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Musculoskeletal-related occupational illnesses and injuries comprise a large majority of military outpatient encounters and result in decreased combat readiness and degraded Soldier performance. The U.S. Army Health Hazard Assessment Program works to reduce health-related adverse consequences from new technology and equipment by identifying and evaluating health hazards during the acquisition of military materiel. This study evaluated the program?s Hazard Inventory database using descriptive statistics in order to determine trends in hazard assessments, database accuracy, and consistency of health hazard communication to materiel developers. It determined that ergonomic-related health hazards are not the most common health hazard type evaluated.

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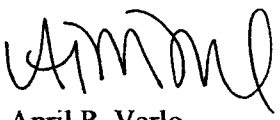

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ABSTRACT

An Analysis of U.S. Army Health Hazard Assessments During the Acquisition of Military Materiel

MAJ April R. Verlo, Masters of Science, 2010

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Musculoskeletal-related occupational illnesses and injuries comprise a large majority of military outpatient encounters and result in decreased combat readiness and degraded Soldier performance. The U.S. Army Health Hazard Assessment Program works to reduce health-related adverse consequences from new technology and equipment by identifying and evaluating health hazards during the acquisition of military materiel. This study evaluated the program's Hazard Inventory database using descriptive statistics in order to determine trends in hazard assessments, database accuracy, and consistency of health hazard communication to materiel developers. It determined that ergonomic-related health hazards are not the most common health hazard type evaluated.

AN ANALYSIS OF U.S. ARMY HEALTH HAZARD ASSESSMENTS DURING THE ACQUISITION OF MILITARY MATERIEL

by

MAJ April R. Verlo

Thesis submitted to the Faculty of the
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CHAPTER ONE: INTRODUCTION

BACKGROUND

The United States of America has the most sophisticated and technologically advanced Army in the world; consequently, we are constantly challenged with the requirement of reducing health hazards associated with the use, maintenance, and testing of new and evolving materiel. As our military capabilities advance, there are evolving challenges in reducing health-related adverse consequences from new technology and equipment. Ensuring the well being of the Soldiers and civilians operating, maintaining, or testing military materiel is paramount to mission success. Occupational illnesses and injuries can result in decreased combat readiness and degraded performance. Many systems consist of hardware and software that require high levels of human performance at tasks necessary for total system effectiveness. Improvements to the interface between the human and the system will help realize the full potential of complex systems (ODUSD(A&T), ODUSD(S&T), 2009). In addition to the inherent dangers associated with military responsibilities, every effort should be taken to prevent Soldier exposure to adverse health risks from the equipment necessary to complete their combat or training missions.

There are multiple examples of weapons systems and other materiel employed by military forces with minimal consideration of their impact on the Soldier as discussed below. Many of the predecessors of today's equipment were initially developed during a time when occupational health was not identified as an area of concern and scientific medical research was focused elsewhere. In the early 1980's, an increased awareness in

Soldier performance decrements led Army leadership and materiel developers to recognize that everyday products or activities can pose potential dangers inherent in their use, composition or disposal. The Textbook of Military Medicine describes multiple examples of the lack of information available during equipment development that exposed personnel to unnecessary health risks (Gross & Broadwater, 1993). The M198 155-mm Howitzer caused chest wall pain and blood in the sputum of the crew, which was later attributed to primary blast injury caused by the physical properties of the blast wave following firing. Limiting the number of rounds fired in a designated time period controlled this injury. Multiple Rocket Launch System (MLRS) crewmembers suffered eye and respiratory irritation following missile launch due to hydrogen chloride entering the crew compartment. Early medical reviews would have recognized this and early recommendations could have prevented the need for an expensive retrofit to compartment seals and the vehicle's overpressure system. The Bradley Fighting Vehicle (BFV) initially exposed crew and passengers to high levels of steady-state noise. Crewmembers were instructed to wear two forms of protective devices to combat hearing loss, which then adversely affected crew communication and vehicle operation. Also, inadequate heating in the BFV affected the crew's ability to operate the vehicle in lower temperatures (Gross & Broadwater, 1993). These health issues were not addressed early in the development process, leading to increased costs from attempts to improve the equipment through retrofits and medical care for short-term side effects. These detriments also prevent Soldiers from performing at maximum efficiency and limit performance.

Using standards and criteria laid out in Federal laws, practices, and guidelines can

minimize risks from these potential hazards (Roberts, 2003). The integration of human performance criteria into the design of Army systems is a significant challenge. Medical research and weapons development activities must work closely to ensure medical problems can be identified and isolated and systems tested to quantify potential hazards. The information needed to adequately assess health hazards associated with a particular piece of equipment provides input to the scope and type of manufacturer testing (AR 40-10, 2007). The knowledge gained during medical testing enables early interventions in the form of redesign or substitutions and a better chance of hazard elimination. Early health risk assessments can provide recommendations for primary prevention strategies such as elimination, product substitution, isolation, process modification or enclosure that prevent exposure to the health risk, while later recommendations may be limited to prevention measures such as emphasizing safety, warning devices and training to minimize effects (Bratt & Evenden, 1995). Early involvement helps ensure timely materiel delivery and incorporates health hazard recommendations in development of system training, operation and maintenance manuals for a system to enhance other health risk mitigation efforts (Bratt & Evenden, 1995). When implemented early, the assessment and recommendations processes also allow maximum considerations for program costs (AR 70-1, 2003).

HISTORY

The Department of Defense (DoD) employs Human Systems Integration (HSI) as a method of ensuring system development accommodates the characteristics of the user population to optimize performance and minimize total ownership costs (DoDI 5000.02,

2008). HSI consists of eight aspects addressing human involvement with the system outlined in DoDI 5000.02 to ensure systems are safe, suitable and supportable. *Human Factors Engineering* minimizes excessive cognitive, sensory or physical skill requirements as well as workload-intensive tasks. The *Personnel* community identifies issues in implementing systems that require skills and abilities in excess of the knowledge and training of current military occupational specialties, while the *Training* community develops individual, collective and joint training for operators, maintainers, and support personnel. *Habitability* representatives establish requirements for the physical environment, personnel services, and living conditions that could have an adverse affect on quality of life or morale. *Manpower* determines the most efficient and cost-effective mix of DoD and contract support to operate, maintain and support the system. Systems that might involve exposure to combat threats require evaluation of *Survivability* issues such as protection against fratricide, detection, the integrity of the crew compartment, and routes of egress if the system is damaged or destroyed. *Safety* and *Occupational Health* efforts determine design characteristics that minimize the risks of acute and chronic illness, disability, injury or death as well as enhance the performance and productivity of those who operate, test, and maintain the materiel.

In 1985, the Army established the Manpower and Personnel Integration Program (MANPRINT) as a method of incorporating DoD directed HSI considerations into the design and development of systems to enhance human performance in the operation, maintenance, support and safety of weapon systems and equipment (AR 602-2, 2001). The Army Health Hazard Assessment (HHA) Program is the lead agent for one of seven domains of MANPRINT, which also includes Manpower, Personnel, Training, System

Safety, Soldier Survivability, and Human Factors Engineering. Each of these programs focuses on integrating Soldier considerations such as manpower structure, personnel aptitudes and training constraints into the Army Acquisitions Process to reduce lifecycle costs, enhance Soldier-system design, and optimize total system performance (AR 602-2, 2001).

Army Regulation 40-10 formally established the Health Hazard Assessment (HHA) Program in 1985 to identify and eliminate health hazards associated with the life cycle management of military weapons, equipment, clothing, training devices and materiel systems and designated the U.S. Army Public Health Command (Provisional) (USAPHC (Prov)) (formerly the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM)) as the lead agency (AR 40-10, 2007). The HHA process uses biomedical knowledge from research or published industry standards to document health hazards and quantify risks to personnel using, testing, or maintaining Army materiel (Gross & Broadwater, 1993). The intent of the program is to apply health protection criteria and standards to a formal system of safety and occupational health risk assessment, with acceptance of risk occurring by an authority commensurate of the risk (AR 40-10, 2007). Efforts to identify and eliminate health hazards from materiel systems links the HHA program directly to Army warfighting capabilities and performance (AR 40-10, 2007).

PROGRAM

Health hazards are conditions that create significant risks of death, injury, acute or chronic illness, disability, and/or reduced job performance to personnel who produce, test, operate, or support military systems (Gross & Broadwater, 1993). Mishaps,

accidents, equipment failures, environmental quality, survivability, system performance, or human factors issues can all be health-related but do not fall within the scope of the HHA Program (AR 40-10, 2007). The primary objective of the program is to "identify and assess health hazards associated with the life cycle management of the following systems and provide recommendations to materiel developers and combat developers to eliminate or control the hazards: weapons platforms, munitions, equipment, clothing, training devices and other materiel systems" (AR 40-10, 2007).

The specific objectives outlined in the HHA Program are to: "preserve and protect the health of individual Soldiers, reduce degradation of Soldier performance and enhance the system effectiveness, design out health hazards to eliminate the need for health hazard-based retrofits, reduce readiness deficiencies attributable to health hazards thereby reducing training or operational restrictions, reduce personnel compensation claims by eliminating or reducing injury or illness caused by health hazards associated with the use and maintenance of Army systems, reduce environmental and occupational health hazards attributable to Army systems" (AR 40-10, 2007).

Mitigation of health hazards is a comprehensive process integrated into all acquisition events: design, testing, manufacturing, operation, maintenance, storage, demilitarization, and disposal. Hazard control is prioritized in the order of engineering controls, administrative controls and the use of personal protective equipment (PPE) (Milz, Conrad, & Soule, 2003). Engineering controls can eliminate hazards through system design, substitution of hazardous materiel, isolation, or modification of hazard source. However, mission requirements do not always facilitate hazard free designs or conditions (Milz, Conrad, & Soule, 2003). Engineering control measures can serve to

minimize hazards where they cannot be eliminated, with preference for more conservative actions that offer the most protection for the user. Designs that reduce the hazard risk, such as a ventilation system to exhaust airborne contaminants, are preferable to safety devices that prevent unintentional use and as a result, possible exposure. Less favorable are warning devices, labels or alarms that warn the user of potential hazards as they occur. Administrative controls, including the development of work practices, training programs, and the use of personal protective equipment are the least preferred methods. These activities are the least successful in decreasing exposures because they rely on personnel to identify hazard opportunities and follow prescribed safety guidelines in order to be effective (AR 40-10, 2007). When properly integrated into the materiel acquisition process, the HHA Program assists in preventing occupational illnesses and injuries as well as enhancing the Soldier's ability to accomplish the mission (Gross & Broadwater, 1993).

Occupational Safety and Health Administration (OSHA) exposure and health protection standards are generally developed to protect personnel from hazards during a traditional 8-hour workday (Code of Federal Regulations Title 29, 2009). Existing OSHA standards may not be applicable to military operations that often involve continuous exposure, multiple exposures or various modes of entry. Military deployment environments are often more extreme, stressful or harmful than civilian workplace environments. There are also military unique operations, equipment or systems that have no civilian equivalent such as combat, tactical vehicles, artillery and other weapons, and certain air or watercrafts. Many existing standards have been deemed unfeasible and require the DoD to develop, publish and follow unique safety and occupational health

standards, rules or regulations to protect personnel. Acceptable exposure limits are derived from application of the risk management process to exposure scenario or hazard specific biomedical research (DoDI 6055.1, 1998). Corporations developing materiel for the military must ensure designs will perform in a military-specific environment while still providing adequate health hazard protection. Testing standards for health hazard mitigation may not be identical to the civilian comparisons that may have been used in initial designs. The HHA Program bridges the gap between the civilian developer and the special military standards, rules, and regulations designed to protect Soldier health. The HHA Program evaluates nine categories of health hazards: acoustic energy, biological substances, chemical substances, oxygen deficiency, radiation energy, shock, temperature extremes, trauma, and vibration (AR 40-10, 2007).

The Army's goal of reducing health hazards must consider mission needs, time, and resources available for research and development, training requirements and limitations once materiel reaches operational use. These considerations ensure optimization of total system performance, minimization of total ownership costs, and ensure the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system (DoDD 5000.01, 2007).

PROCESS

The HHA Program utilizes environment, safety, and occupational health (ESOH) risk management to determine whether systems are environmentally acceptable, safe, and pose minimal possible health risk. Risk assessment codes (RAC) estimate the degree of risk associated with each hazard and aid in decisions that will establish priority for

control measures in the risk determination process. Health risk levels are based on scientific, unbiased, objective, conservative criteria that apply quantitative and qualitative measures (AR 40-10, 2007). The RAC estimates the probability and severity of an adverse health event that could result from a specific exposure and may range from 1 (very high risk) to 5 (very low risk). Hazard severity describes the most reasonable health consequence to Soldiers associated with the normal use of the system. The consequence is directly related to the specific physical, chemical or biological stressor and is placed in the following categories (outlined in Table 1).

Table 1
Hazard severity

Level	Description	Effect on item, fleet, or inventory
I	Catastrophic	Hazard may cause death or total loss of a bodily system
II	Critical	Hazard may cause sever bodily injury, severe occupational illness or major damage to a bodily system
III	Marginal	Hazard may cause minor bodily injury, minor occupational illness, minor damage to a bodily system
IV	Negligible	Hazard would cause less than minor bodily injury, minor occupational illness or minor bodily system damage

Source: Army Regulation 40-10. *Health Hazard Assessment Program in Support of the Army Acquisition Process.* Army Regulation, Washington DC: Headquarters Department of the Army, 2007.

Hazard probability is the likelihood of the adverse health effect occurring during normal materiel use. This determination is based upon factors such as location, exposure and the effected population. The exposure probability is determined differently for single items compared to an entire fleet or inventory of items. The hazard probability is placed in one of the categories outlined in Table 2.

Table 2
Hazard probability

Level	Description	Effect on item, fleet, or inventory
A	Frequent	Likely to occur often to a specific individual item, a fleet or inventory will continuously experience
B	Probable	Will occur several times in the life of an item, or frequently in a fleet or inventory
C	Occasional	Likely to occur sometime in the life of an item, will occur several times in a fleet or inventory
D	Remote	Unlikely, but possible to occur in the life of an item, unlikely but reasonably to be expected to occur in the inventory
E	Improbable	So unlikely it can be assumed occurrence may not be experienced, unlikely to occur but possible in an inventory

Source: Army Regulation 40-10. *Health Hazard Assessment Program in Support of the Army Acquisition Process.* Army Regulation, Washington DC: Headquarters Department of the Army, 2007.

The combination of the hazard severity and hazard probability leads to the RAC as shown in Table 3.

Table 3
Risk assessment matrix

Risk Assessment Code					
Hazard Severity Categories	Hazard Probability Levels				
	A	**B**	**C**	**D**	**E**
I	1	1	1	2	3
II	1	1	2	3	4
III	2	3	3	4	5
IV	3	5	5	5	5

Source: Army Regulation 40-10. *Health Hazard Assessment Program in Support of the Army Acquisition Process.* Army Regulation, Washington DC: Headquarters Department of the Army, 2007.

Health risk assessment is continuous throughout the phases and milestone decision points in the Defense Acquisition Process. The process begins with the identification of a

shortfall in current capabilities that is necessary for successful mission accomplishment. *Materiel Solution Analysis* defines the desired capabilities, metrics of performance and operational requirements to resolve the capability deficit. During this phase, the independent medical assessor reviews historical health hazard data on predecessor or similar systems, reviews new system designs, identifies potential health hazard issues and communicates health criteria and performance standards that recommend means to eliminate, control or reduce risks to the developer (Gross & Broadwater, 1993). During the *Technology Development Phase*, combat and materiel developers use the initial HHA recommendations to influence design engineering to eliminate hazards and conduct testing and evaluation on any unresolved hazards. Once testing and evaluation are complete, health hazard data are utilized to verify the effectiveness of recommended health hazard controls and to evaluate residual health risks to update the HHA. The HHA provides information to make decisions regarding accepting risk associated with major hazards (Gross & Broadwater, 1993). The *Engineering and Manufacturing Development Phase* of the acquisitions process is where materiel developers ensure any special procedures to mitigate remaining health risks are incorporated into doctrine and publications. During the *Production and Deployment Phase* the HHA Program continues to review efforts to minimize any unresolved health hazards. Formal HHA activities end once the design is stabilized and the materiel enters full-rate production and deployment (AR 40-10, 2007).

LITERATURE REVIEW

Initial keywords used to identify comparable studies and programs included: health hazard, occupational, Army, military, risk, exposures, history, disability, assessment, materiel, injury, illness, hazard analysis, intervention, and acquisitions. Combinations of these keywords and terms such as mitigation, prevention and design were also used. The search of electronic resources included PubMed, Ovid MEDLINE, Elsiever EMBASE, Science Direct, Google Scholar, Bureau of Labor Statistics (BLS), Occupational Safety and Health Administration (OSHA), and the National Institute for Occupational Safety and Health (NIOSH). The search produced studies and information from peer-reviewed journals, military and government regulations, industry standards, edited books and many web-based sources. The search provided research in primarily three distinct categories; studies done on specific injury types in civilian or military populations, civilian health and safety programs, and military risk reduction efforts.

Studies outline general occupational illness and injury trends in population subsets, but are usually specific to one type of hazard. Research specific to hazard types are further discussed in Chapter 2. Sources were excluded if they evaluated the effects of other physiological and descriptive demographics such as education, pay grade, or gender on occupational illnesses (Tiesman et al., 2007; Choi, 2009). Studies that focus on administrative controls used to minimize health effects after materiel is in use, rather than hazard mitigation efforts during the engineering or design of materiel, were excluded (Suter, 2009; Chou, Lai & Kuo, 2009). Most commonly, studies investigate disability and injuries within the DoD, but do not distinguish between illness and injury resulting from an occupational exposure or from a safety-related accident (Lincoln et al., 2002; Parrish, Olsen & Thomas, 2005). The review excludes sources evaluating accidents, or

injuries not resulting from standard occupational exposures, subjective studies, and studies that evaluate the effects of hazards from non-occupational sources, such as exercise or environmental conditions. The Defense Medical Surveillance System (DMSS), and the Composite Health Care System (CHCS) used by the military to document patient encounters do not distinguish between injuries as a result of occupational health hazards, the focus of the HHA Program, or as a result of accidents or mishaps. These data limitations do not allow a direct relationship between occupational injury rates and health hazard mitigation actions to be made. However, these data are useful in providing overall trends.

In the civilian sector, standards and regulations relating to the protection of workers from occupational health hazards are the responsibility of agencies such as OSHA, the Environmental Protection Agency (EPA), the Department of Health and Human Services (HHS), and the Food and Drug Administration (FDA) (Code of Federal Regulations Title 29 2009, Occupational Safety and Health Act of 1970).

The HHA Program applies a multitude of disciplines such as civilian occupational health, preventive or environmental medicine, industrial hygiene, safety and pollution prevention programs to military scenarios. A comparable all-encompassing program in the private sector is the National Safety Council Institute for Safety through Design. This program was established in 1995 after safety professionals realized many occupational injuries could be attributed to design flaws. The Council's mission is to integrate hazard analysis and risk assessment methods early in design and engineering activities to significantly reduce the risk of injury or illness, increase production and avoid expensive retrofits (Manuele, 2008). In 2007, the National Institute for Occupational Safety and

Health (NIOSH) began the National Prevention through Design (PtD) Initiative (Schulte, Rinehard, Okun, Geraci, & Heidel, 2008). The PtD encourages business decision makers to anticipate and design specifications to prevent and minimize potential occupational safety and health risks. It supports considerations in construction, maintenance, decommissioning and disposal, and recycling of waste materiel. This initiative also aims to move the responsibility of occupational safety and health considerations away from individual workers and up to higher level decision makers (Schulte, Rinehard, Okun, Geraci, & Heidel, 2008). Process Hazard Analysis (PHA) is a regulatory requirement under Title 29, Code of Federal Regulations (CFR), Part 1910.119(e) that requires employers to identify, evaluate and control highly hazardous chemical substances associated with industrial processes. The methods of evaluating potential health hazards are comparable even though the PHA incorporates safety aspects, while the HHA Program does not, and the military rarely manufactures items. The PHA program considers the extent of the hazard, number of potentially affected employees and operating history of the process to assess compliance with existing health, safety and environmental regulations. The PHA addresses potential catastrophic consequences, engineering and administrative controls, personal protective equipment and procedures, and a qualitative evaluation of possible employee health effects (Shah, 2008). The International Occupational Hygiene Association (IOHA) is working to develop qualitative risk assessment and management approaches for ergonomic, chemical, safety, psychosocial, and sector specific risks to provide small businesses in underdeveloped economies with practical means to control hazards at work (Fingerhut, 2008). The aim of IOHA is to provide the means for employers that lack the expertise or capital the ability

to conduct qualitative risk assessments and control exposures to complement existing traditional engineering controls in the workplace (Fingerhut, 2008).

Private sector programs have encountered barriers to incorporating health hazard mitigation through design. Designers, engineers, and safety professionals often work exclusively within their specialty and potential hazards can be overlooked if they fall outside the individual's area of expertise (Zarges & Giles, 2008). Economic impacts of both direct and indirect costs pertaining to implementing less hazardous designs or the projected benefits of reduced healthcare costs, higher productivity and better quality are not well understood (Gambatese, 2008; Howe, 2008). Not recognizing these tangible benefits could lead to cost-savings initiatives that result in a reduction in a company's health and safety efforts (Shah, 2008). Most importantly, civilian contracts and procurement officers do not have an enforceable requirement for conducting safety reviews or operational risk assessments (Zarges & Giles, 2008). The HHA required by the DoD during development allows collaboration by several entities. For example, combat developers work closely with designers and independent medical assessors to ensure issues are identified and adequately addressed.

The British Armed Forces have also identified occupational health risks as an area requiring greater attention. Health Risk Management instruction teaches British Forces how to implement a process to monitor the interventions aimed at reducing risk from occupational health hazards before they are detected by medical surveillance systems. Legislation in the United Kingdom has determined a hierarchy of control activities similar to those of the DoD, preferring removal of the hazard to controlling exposure or issuing personal protective equipment (Bricknell & Moore, 2007).

All DoD entities are required to implement HSI considerations during the acquisitions process. The United States Navy and Marine Corps Public Health Center (NMCPHC) (formerly the Navy Environmental Health Center) is responsible for performing assessments and publishing guidance for controlling potential health hazards for the U.S. Navy. Navy programs involved in research, development, testing or evaluation request NMCPHC support during early development activities to ensure health hazards are identified and recommendations made for surveillance and control (BUMEDINST 6270.8B, 2008). A major difference from the Army HHA Program is that the Navy uses a tiered approach to assess health risks, particularly for toxic materials. Non-health professionals use standardized criteria published by OSHA and American Conference of Governmental Industrial Hygienists (ACGIH) to screen potential materials for known health risks. If the materiel's health risk potential cannot be determined, or if it cannot be adequately controlled, the supporting regional occupational health department reviews the materiel to determine potential risks. If uncertainty still exists, the request is then forwarded to NMCPHC for evaluation (National Research Council, 2000). Following a lapse in formal design-focused hazard mitigation efforts, the Naval Safety Center is taking a larger role in Navy acquisition committees to help develop preliminary hazard lists and identify potential alternative approaches to risk mitigation in the areas of confined space entry, ergonomics, fall protection, heat stress, lasers, noise, non-ionizing radiation, ventilation and vibration (Geiger, 2008; Geiger & Ruttenberg, 2006; Naval Safety Center, 2009). They apply regulatory criteria and standards to evaluate underlying risk to develop safer and more efficient systems and equipment

rather than relying on regulatory compliance, administrative procedures and protective equipment to mitigate hazards (Geiger, 2005).

The United States Air Force conducts assessments of potential health hazards as part of the system safety program established for each system acquisition. They identify physical, biological, ergonomic and chemical hazards involved with the system and supporting logistics requirements then estimate the means and frequency of exposure in order to incorporate cost-effective controls into the design of the system (Air Force Safety Center, 2000). Hazards are assigned a mishap risk assessment, similar to a RAC, which is used to determine the management level for risk acceptance as well as to prioritize resources to resolve risks (Air Force Safety Center, 2000). A major difference in the Air Force system safety approach is that health hazards are not limited to routine occupational exposures, but include mishaps and other damage due to human error or environmental condition. Other aspects of the system safety program include operational safety of flight, ground, and weapons hazards, nuclear, explosives, facility, missile and range safety that can be concerns in airborne operations because of dangers involving flight operation mishaps in uncontrolled areas (Air Force Safety Center, 2000).

OBJECTIVES

Occupational-related health hazards present a major public health problem. Days lost to injury reduce productivity; injuries also increase costs due to health care, non-working employee wages, and disability claims. Incidence rates of non-fatal occupational injuries and illnesses have been declining in private industry since 2003, occurring at a rate of 3.9 cases per 100 equivalent full time workers in 2008 (Bureau of

Labor Statistics, 2009). Musculoskeletal disorders accounted for the largest portion at 29% of all workplace injuries and illness requiring time away from work in 2008 (Bureau of Labor Statistics, 2008). The DoL defines musculoskeletal disorders as those where the nature of injury is a sprain, strain, back pain, damage to the muscular or skeletal systems or connective tissue. These injuries result from activities such as reaching, twisting, overexertion or repetition (Bureau of Labor Statistics, 2008). The largest portion resulted from sprains and strains due to overexertion. Even though the military population is generally considered to be physically fit, occupational musculoskeletal disorders have been a predominant source of military outpatient visits, especially for occupational specialties that involve heavy physical demands, awkward postures, pushing or pulling, and overhead lifting (Fabrizio, 2002; Feurstein, Berkowitz & Peck Jr., 1997).

This study's hypothesis evaluates the U.S. Army's Health Hazard Inventory (HI) database to determine if ergonomic-related conditions with the potential to cause death, injury, illness, disability, or reduced job performance, are the most common of the health hazard types evaluated by the HHA Program. The specific aims will (a) determine frequency and severity of health hazard types, (b) determine whether each of the health hazard data requirements are consistent with current scientific knowledge and clearly communicated to materiel acquisition program managers during the materiel acquisitions process, and (c) will evaluate a sample of the database for accuracy by comparing the data entries to original reports to determine if it is at least 95% accurate.

CHAPTER TWO: HEALTH HAZARDS

INTRODUCTION

The USAPHC (Prov) evaluates potential health risks that exist in materiel in the acquisitions process in order to identify and mitigate potential issues that can adversely impact Soldier health and well-being.

The DoD is required to comply with safety and occupational health standards established by the OSHA and other non-DoD regulatory standards for equipment, systems, operations or workplaces as completely as practicable (Code of Federal Regulations Title 29, 2009). The military must comply with EPA regulations on air pollution, drinking water, liquid and solid wastes, hazardous and infectious wastes and pesticide use (AR 200-1, 2007). When military designs, specifications or deployment requirements don't allow compliance with industry or regulatory standards, or if no standard exists for an application, DoD can propose an alternate standard for implementation (DoDI 6055.1, 1998). These alternate standards will apply the health risk management process to injury criteria and research to develop standards that are compatible with Federal occupational safety and health standards, ACGIH Threshold Limit Values (TLV) or specifically adopted consensus standards (AR 40-10, 2007). The program doesn't evaluate potential health hazards that fall under regulatory guidelines of other Federal agencies such as the FDA or the Federal Aviation Administration (FAA) if the military intends to use the materiel for its original purpose (AR 40-10, 2007).

Historical reports from the electronic archive at USAPHC (Prov) were used to compile standardized Initial HHA Report (IHAAR) elements that encompassed a description of the hazard, data necessary for a health risk evaluation, initial

recommendations, health effects, and medical criteria of each health hazard. Each of the categories of potential health risks were compared to current scientifically accepted and military-unique standards. The requirements for each of the hazard types were compared to regulatory requirements outlined by their respective industry standards, International Organization for Standardization (ISO), OSHA, and military specific standards based upon research conducted at the U.S. Army Test and Evaluation Center or similar organizations.

There are 18 hazard types evaluated by the HHA Program, 16 standardized IHHAR elements included in this study resulted from the comparison of military standards to current scientific knowledge as part of one specific aim of this study. The IHHAR elements are attached as Appendixes A through P. These standardized documents are used in Chapter 3 to evaluate the consistency of past assessments when communicating data requirements to materiel developers. Three hazard types do not have models, methods, tools or applications fully developed or utilized to adequately determine health risk. These hazard types are head supported mass, acceleration/deceleration, and blunt and sharp trauma. Of these three, head supported mass is included as a standardized IHHAR element and only contains general guidelines for materiel developers. The hazards are described here outline the health hazards evaluated by the HHA Program for familiarization, provide a summary of the potential adverse health effects resulting from occupational exposure, and outline the regulatory requirements provided to materiel developers during the HHA process.

ACOUSTIC ENERGY – STEADY-STATE NOISE

Acoustic energy propagates through the air as pressure waves and interacts with the body (USACHPPM, 1996). Noise is all essential and unwanted sound formed by those pressure waves. Steady-state noise is a variation around the ambient atmospheric pressure exceeding one second in duration. Excessive noise can be continuous and not vary with time, intermittent if broken by periods of very low noise levels, or fluctuating if the sound pressure varies over a wide range (USACHPPM, 1996). Steady state noise from weapons, vehicles, generators, aircraft, and power tools pose occupational risks to hearing in the military community.

High intensity noise can cause a loss of hearing sensitivity that can be recovered if exposure is short-term. However, with repeated long-term exposure, the loss becomes permanent (Bruce, Bommer, & Moritz, 2003). Noise induced hearing loss is usually painless, progressive and the onset is not easily perceptible. Approximately 25% of Americans over the age of 65 suffer from hearing loss to some degree (Clark & Bohne, 1999). Other symptoms of noise exposure are ringing in the ears (tinnitus) and temporary muffling of sounds after exposure. Both can result in a reduction in communication ability that can be detrimental to survival in combat situations. Reduced hearing sensitivity at frequencies above 2000 hertz (Hz) is characteristic to the onset of noise-induced hearing loss from unprotected exposure to steady-state or impulse noise (DA PAM 40-501, 1998). The ideal control option is reducing noise levels at the source through engineering controls. In unmitigated noise hazard conditions, minimization of time spent in a noise hazardous area and the use of hearing protection devices are the next preferred option.

Civilian DoD employees follow OSHA permissible exposure limits for occupational hazardous noise, which is a time-weighted average (TWA) of 90 decibels, A-weighted for human auditory sensitivity (dBA) (Code of Federal Regulations Title 29, 2009). The Army adopted stricter requirements and determined exposure to steady-state noise levels of 85 dBA or more for eight hours out of a 24-hour period to be hazardous, with prolonged exposure increasing the risk of permanent hearing loss (DA PAM 40-501, 1998). Exposure exceeding eight hours per day can be considered hazardous at levels above 75 dBA (NIOSH, 1998). This can be a concern during combat operations because Soldiers cannot always adhere to a conservative schedule as mission dictates necessary activities.

The MIL-STD 1474D Requirement 1 outlines data for collecting noise levels particularly in the 85 dBA noise contour emitted by materiel during each unique operational condition at positions around the materiel occupied by operators, maintainers, testers, or passengers.

ACOUSTIC ENERGY – IMPULSE NOISE

The difference between impulse and steady state noise is primarily event duration. Common sources of impulse noise in the military are weapons firing, exploding munitions, release of pressurized gasses and object impacts. Impulse noise high-level, short duration exposures to acoustic energy above 140 dBA risks stretching inner ear tissues beyond their elastic limits, ripping or tearing them apart (Clark & Bohne, 1999). This is referred to as acoustic trauma, which occurs rapidly and results in an immediate, permanent hearing loss (Clark & Bohne, 1999). A loss in hearing sensitivity following

an impulse noise event can have adverse effects on mission success, as it will impair the use of communication and other auditory equipment.

Impulse noise exposure limits published in MIL-STD 1474D and DA PAM 40-501 originated with the National Research Council Committee on Hearing, Bioacoustics and Biomechanics (CHABA) Working Group 57 in 1968 to set safe exposure limits to gunfire in the absence of hearing protection. The criteria were developed to protect 95% of exposed personnel from significant permanent hearing loss after a career of occupational exposure (USACHPPM, 1996). OSHA regulations and ACGIH TLVs recommend no exposures above the 140 dBA peak without hearing protection (ACGIH, 2010). The ISO 1999 and ANSI S3.28-1986 use a different approach to estimate impulse hazards by including them with steady state noise hazards. While this simplifies the estimation of risk into one exposure, it limits the number of impulses allowed below 140 dBA and decreases the allowable exposure to each type of noise individually (International Standard, 1990; ANSI S3.28-1986, 1986). The duration of the impulse at the peak pressure level (dB) and the kind of hearing protection used determines the number of impulse noise event exposures allowed in a 24-hour period. These additional allowances are provided in MIL-STD-1474D for large caliber artillery up to 190 dB impulses to accommodate combat weapon effective range and velocity requirements (USACHPPM, 1996).

The MIL-STD-1474D Requirement 4 outlines testing requirements and measurement techniques to determine compliance with acoustical noise standards. Measurements are made in noise contours, which outline the noise level at defined distances and directions from the source. Special attention must be made to determine

the 140 dB contour for all operator, passenger, maintainer, and tester positions to provide the most accurate assessment.

ACOUSTIC ENERGY – BLAST OVERPRESSURE

Explosive forces generated by the firing of weapons or ordinance cause blast overpressure hazards. Expanding gasses compress surrounding air and generate a shock wave that can be propagated through the body (Clemedson, 1956). Air-containing organs such as the heart, lungs and stomach are susceptible to the absorption of a shock wave capable of disrupting the structure and function of the cells through compression, expansion, and pressure differentials (Leung, VandeVord, Leonardi Del Cengio, Bir, Yang, & King, 2008). Recent studies suggest possible neurological effects in addition to pulmonary edema, lung lacerations, blood in alveolar cavities and hemothorax injuries that are frequently seen (Leung, et al, 2008).

An approved blast test device placed in locations that weapon crew personnel occupy during live firing collects data for analysis. Software records time and pressure data from the device to calculate the mechanical force the blast would yield and estimates the probability of tissue damage (BOP Program Guidance, 2005).

The materiel developer must conduct testing in accordance with guidance published by the USAPHC (Prov) Ergonomics Program and submit the data in the appropriate format for evaluation (BOP Program Guidance, 2005).

BIOLOGICAL SUBSTANCES – PATHOGENIC ORGANISMS (BLOODBORNE)

Exposure to blood borne pathogens can occur during patient care, cleaning, maintenance, or improper disposal of contaminated equipment, supplies or blood products. Potentially infectious materials put personnel at risk of exposure to human immunodeficiency virus (HIV), hepatitis B virus (HBV), hepatitis C virus (HPC) and other potentially infectious agents (Code of Federal Regulations Title 29, 2009).

Universal precautions and a comprehensive blood borne pathogen program identifying risks, exposure control plans, compliance, hazard communication, training and record keeping are required (Code of Federal Regulations Title 29, 2009). In addition, military materiel must be designed to segregate regulated medical waste (RMW) and contaminated clothing or equipment from general waste and stow it until mission completion or proper disposal is possible.

Materiel developers must provide essential information contained in 29 CFR Part 1910.1030, regarding the scope, exposure control plans, methods of compliance, vaccinations, training, record-keeping, and post-exposure evaluation plans. They must also design the materiel for decontamination, make provisions for storing RMW, and incorporate hazard information in training and operation manuals.

BIOLOGICAL SUBSTANCES – PATHOGENIC ORGANISMS (WATERBORNE)

Providing an adequate supply of potable water to Soldiers is critical to maintaining health and operational readiness. Insufficient water can quickly lead to dehydration as physical work, environmental stress, clothing, and equipment necessary in military environments all increase water losses (TB MED 507, 2003).

Water must be free of chemical, microbiological and other contaminants that will cause short-term illnesses such as gastroenteritis, skin or eye infections, occupational asthma or hepatitis that could have detrimental effects on Soldier performance (TB MED 577, 2005; Thickett, McCoach, Gerber, Sadhra & Burge, 2002). The military has developed deployed water quality standards known as the Tri-Service Field Water Standards to outline required physical and chemical characteristics of water. These standards incorporate the EPA National Primary Drinking Water Standards (NPDWS) maximum contaminant levels (MCL) and are designed to minimize overall unit degradation, even though a few individuals could be adversely affected (TB MED 577, 2005). In addition, USAPHC (Prov) has developed exposure guidelines for toxic industrial chemicals to prevent delayed or long-term health effects from personnel consuming contaminated water supplies. The guidelines outlined in Technical Guide (TG) 230 are developed for a military population that is assumed to be healthy and fit and less susceptible to the adverse health effects in the general population. This would exclude certain populations such as those medically excluded from military service, the elderly, and children. Although there are subpopulations that may be uniquely susceptible (pregnant women or asthmatics), the military exposure guidelines (MEG) in TG 230 represent conservative population thresholds where an effect may be noticed in a small percentage of exposed personnel (USACHPPM TG 230, 2003). Military specific modifications to the NPDWS also include the addition of short-term chemical warfare agents, duration of exposure, and overall increased consumption amounts. The typical military standard for water consumption is 5 liters per day (L/day) for moderate climates

and 15L/day in arid or dry climates, which greatly exceed general population consumption rates of 2L/day (USACHPPM TG 230, 2003).

There are five criteria necessary for the HHA Program to assess water-borne pathogenic organism health hazards. Materiel developers must provide water treatment procedures, design specifications, materials and chemicals used, and outline administrative, design and engineering controls to prevent occupational exposure to water-borne pathogens. Testers must assess the materiel's ability to provide water commensurate with national and military standards during missions of extended duration as well as in extreme temperature conditions, under vibrational stress, and in dusty environments to determine if water quality standards can be upheld when the equipment is under physical stress (USACHPPM, 1996). Developers must provide water quality analysis results to USAPHC (Prov) for completion of the HHA.

BIOLOGICAL SUBSTANCES - SANITATION

Military training and combat operations frequently occur in harsh environments where modern facilities are not available. Ingestion, inhalation of or contact with pathogenic microorganisms, their toxins and enzymes can cause a variety of illnesses such as zoonotic diseases, adverse respiratory or gastrointestinal symptoms, dermatitis which can result in noncombat related lost time (USACHPPM, 1996). Historically, poor sanitation has been a leading cause of disease and non-battle injuries affecting the outcome of military campaigns (Withers & Craig, 2003).

Independent medical assessors must look at numerous facets of sanitation to characterize the overall risk to Soldier health such as potable water supply, waste

management, foodservice sanitation, toilet and shower facilities, laundry services, and pest control operations (USACHPPM, 1996). Ensuring materiel meets regulatory civilian guidelines is appropriate in many circumstances such as for food service equipment used at fixed dining facilities on established military installations. However, human waste disposal during combat requires special considerations to maintain a sanitary environment in a unique military scenario.

Typical combat operations do not occur where existing water distribution infrastructure is considered safe for use, water must be transported to the point of consumption. This adds additional risk considerations, as there is potential for gross or cross-connection contamination of the container. The materiel must be suitable for potable water contact while conforming to military equipment requirements for suitability. All potable water transport, storage and distribution materiel used by the Army must meet criteria outlined by the National Sanitation Foundation (NSF) and conform to the Uniform Plumbing Code (UPC) (IAPMO/ANSI UPC, 2009; NSF/ANSI, 2009; TB MED 577, 2005). They must also be able to support the intended user population for all operational scenarios and undergo an American Water Works Association (AWWA) cross-connection control survey (American Water Works Association, 2004; USACHPPM, 1996).

Wastewater disposal systems and incinerators must be able to support the intended population for the duration of the mission to reduce hazards from contact with pathogenic organisms. Army policy requires disposal of waste in a manner that protects both the environment and human health (AR 40-5, 2007).

Foodservice equipment and utensils must meet applicable civilian standards of the NSF, Underwriters Laboratory (UL) or other national consensus standards (TB MED 530, 2002). In addition, foodservice equipment must demonstrate the ability to maintain applicable standards of heating and cooling outlined in the FDA Food Code when utilized in austere environments to prevent the spread of food-borne illness.

Toilet and shower facilities must meet requirements found in Federal regulations (29 CFR 1910.141); be constructed so that they do not leak, can be thoroughly cleaned and maintained, and contain provisions for hand washing or sanitizing body contact surfaces. Military requirements for toilet facilities require they accommodate the total number of personnel for the required mission duration, as the materiel is generally designed for use in environments without access to sewage disposal systems to remove waste on a consistent basis.

In addition to system design and operation specifications, materiel developers must provide documentation that materiel meets applicable UPC, UL, 29 CFR 1910.141, or NSF criteria and water-handling equipment has undergone an AWWA cross-connection survey. Developers must outline disinfection procedures and specifications of reverse osmosis elements if applicable. All occupied structures and waste collection areas must have pest exclusion devices. Any system with the potential for condensate must have provisions to prevent the accumulation of stagnant water.

CHEMICAL SUBSTANCES

Weapons combustion products, engine exhaust from vehicle engines and generators, smokes and obscurants, chemical agents and fuel, oil, lubricants, cleaners, solvents, fire

extinguishers, battery acids and chemical refrigerants used in maintenance or logistics operations expose Soldiers to a variety of hazardous chemical substances and toxic gases (Roberts, 2003). Chemical hazards arise from excessive concentrations of mists, gases, vapors, fumes or particulate matter that can be inhaled, ingested, absorbed, or injected and cause toxic effects (Schaper & Bisesi, 2003). Depending on the duration and level of exposure to specific chemicals, Soldiers can suffer a variety of health effects ranging from decreased performance to death.

Army exposure standards for chemical substances incorporate numerous industry standards for non-military unique occupational applications. The primary source is OSHA regulatory limits. However, where no OSHA standard exists or if the OSHA standard is less stringent, ACGIH TLV exposure guidelines are used. When Federal agencies have regulatory oversight on a workplace, such as the Department of Transportation (DOT) or the EPA, those standards are used for those comparable occupational applications (USACHPPM, 1996). Some chemicals are more frequently found in military settings or the exposure duration, frequency or concentration is significantly different than civilian occupational comparisons (Roberts, 2003). The chemical substances with frequent military-unique health risks are carbon monoxide, fog oil, and chemical warfare agents (DA PAM 40-8, 1990; MIL-STD-1472F, 1999; Technical Report No. 9010, 1990).

Developers must collect information on the chemical composition of any propellants and engine exhaust in accordance with Test Operating Procedure (TOP) 2-2-614 and provide it to the USAPHC (Prov) for analysis. They must also provide the material

safety data sheets (MSDS), chemical composition, purpose, and quantity of any miscellaneous chemicals used in the operation or maintenance of materiel.

OXYGEN DEFICIENCY

Ventilation of occupied spaces provides adequate fresh and recirculated air for breathing and aids in the elimination of toxic chemicals, airborne dust and droplets by means of local exhaust, natural or dilution air supply. It also contributes to the comfort of personnel and to worker health since ventilation aids in controlling odors, temperature and humidity and communicable diseases spread by airborne contaminants (Burge, Hoyer, Gunderson, & Bobenhausen, 2003). Inadequate ventilation accounted for 52% of indoor air quality problems encountered by NIOSH in the past decade (Occupational Safety and Health Administration, 2008).

OSHA recommends adhering to the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 62 to define indoor environments with respect to temperature (68 – 76 ^{o}F), thermal radiation, humidity (< 60%), air speed, and ventilation rates of 15 – 20 cubic feet per minute per person (cfm/person) to make environments acceptable to 80% of the occupants within a space (ASHRAE, 2004).

The MIL-STD-1472F contains the most restrictive fresh air requirement for enclosures, shelters or vehicle cabs at approximately 20 cfm/person. The TOP 1-2-610 outlines mandatory test data such as maximum personnel occupancy, area volume, and total fresh and recirculated airflow rates. Developers must submit the data for all military use scenarios. Confined spaces with oxygen levels less than 19.5 % or above 23.5%, limited means of entry or exit, potential to engulf an entrant, not designed for continuous

occupancy or with another health or safety hazard present must follow OSHA guidelines outlined in 29 CFR 1910 to protect employees from hazards (OSHA, 2008).

RADIATION ENERGY - OPTICAL RADIATION

Laser and optical radiation hazards exist along a beam path of concentrated wavelengths of light. Military lasers are used in non-lethal weapons, high intensity lights, target acquisition devices, radars, laser countermeasures, and fire direction control equipment on systems designed for combat.

The eye is the most vulnerable to injury from optical radiation. Effects are dependent upon the wavelength of the hazard and can damage the retina or cornea, ranging from simple reddening or production of an afterimage to clouding, hemorrhage or lesions that permanently alter the physical structure of the eye resulting in permanent damage (Hitchcock, Moss, Murray, Patterson, & Rockwell Jr., 2003). Adverse health effects resulting from skin exposure to optical or laser radiation between 315 nanometers and 1 millimeter in wavelength vary from mild reddening to blistering and charring, depending primarily on the power of the exposure, total energy absorbed, and how quickly the particular location on the body can conduct the heat away (Hitchcock et al., 2003).

Normally, the manufacturer will certify a commercial system using the Federal laser standard, 21 CFR 1040 (Code of Federal Regulations Title 21, 2009). The unique nature of some military equipment designed specifically for combat operations, combat training or national security applications sometimes results in those devices not being required to comply with all the performance requirements of the Federal laser standard but must

meet alternate military standard requirements (MIL-STD-1425A, 1991; TB MED 524, 2006). The Laser/Optical Radiation Program at USAPHC (Prov) evaluates hazard probability and severity, and ocular maximum permissible exposures (MPE) for eye and skin exposures based on the laser or optical radiation characteristics and intended use scenarios.

The independent medical assessors at USAPHC (Prov) developed a form to provide to customers needing hazard evaluations on systems. Developers must provide information on the source, operating modes, transmitter wavelength, maximum output power, maximum energy per pulse, pulse repetition frequency, exit beam diameter, divergence, distribution profile and medium as well as any safety features and dayview optics for completion of the HHA.

RADIATION ENERGY - RADIOFREQUENCY RADIATION

Radiofrequency radiation (RFR) refers to the non-ionizing portion of the electromagnetic energy spectrum between 3 kilohertz (kHz) to 300 gigahertz (GHz). This type of radiation is emitted by military communication systems, and surveillance and target acquisition radars.

The primary effect of absorbed RFR is cellular temperature increase leading to possible secondary effects including redness, tissue damage, cataracts and burns if the heat is not dissipated (Hitchcock, Moss, Murray, Patterson, & Rockwell Jr., 2003). RFR energy can also induce electrical currents in the body, producing shock effects and stimulating nerves or muscles if above 140 volts (V). Excess thermal stress from upper frequency bands effect the eyes and skin while lower frequencies can affect internal

organs by deep-body heating or induced currents (ACGIH, 2010; ANSI/IEEE, 2005; Hitchcock et al. 2003).

The Army, DoD and OSHA have based exposure guidelines on those of the ANSI/Institute of Electrical and Electronics Engineers (IEEE) C95.1 and C95.6 standards with an automatic safety factor of 10 incorporated. Maximum permissible exposures (MPE) at frequencies below 5 megahertz (MHz) are established to limit adverse health effects due to electrostimulation, The MPEs between 100 kHz and 3 GHz limit specific absorption rates, and MPEs in frequencies between 3 GHz and 300 GHz are established to limit health effects due to incident power density. Military specific high-peak power-pulsed fields and electromagnetic pulses are limited to 200 kilovolts per meter (kV/m) based upon North Atlantic Treaty Organization (NATO) Standardization Agreement 2345 (DoDI 6055.11, 2009; NATO, 2003).

Necessary criteria to compute the root mean square (rms) electric field strengths for comparison against MPEs include frequency and peak, average power output, pulse repetition frequency and pulse width, duty cycle, and information regarding antenna size, gains and location.

RADIATION ENERGY - IONIZING RADIATION

Ionizing radiation consists of particles or electromagnetic energy capable of detaching electrons from atoms or molecules when passing through matter. Hazards are in the form of alpha or beta particles, gamma rays, neutrons or x-rays.

The effects of ionizing radiation in biological systems depend on the amount of radiation absorbed and the molecules affected (Cember & Johnson, 2009). The ionizing

radiation causes molecules to break into charged parts or rearrange, causing permanent damage to cells. Low doses of ionizing radiation primarily increase risks of cancer, can effect growth and development of cells, have effects on fertility, and genetic effects in offspring are possible but unlikely (Cember & Johnson, 2009).

The Nuclear Regulatory Commission (NRC) and Titles 10, 21, and 29 in the CFR govern ionizing radiation sources used by the military. The primary limit established by the NRC to prevent or minimize potential health risks is an effective dose not exceeding 50 millisievert (mSv) per year. Any occupationally exposed Soldier likely to receive more than 5 mSv per year must have a personal dosimeter to monitor their individual dose in accordance with procedures outlined in Department of the Army Pamphlet (DA PAM) 385-24 and AR 385-10.

Data necessary to evaluate potential health hazards resulting from exposure to ionizing radiation from radioactive sources include verification that the materiel meets applicable NRC, CFR, or American National Standards Institute (ANSI) requirements, identifies the isotope, the condition and physical form, and the emission or decay rate. Developers must provide specific information on x-ray devices including operating parameters, radiation output, and system certification in accordance with 10 or 21 CFR. Neutron source information includes operating parameters, neutron emission rate and average energy emitted. The NRC or Department of the Army (DA) must authorize all radioactive sources and x-ray devices (DA PAM 385-24, 2009). Developers must also outline storage, use, maintenance, disposal and special handling requirements of any radioactive sources.

TEMPERATURE EXTREMES

Health hazards due to temperature extremes are the result of interactions between mission, environmental factors, and physiological factors. The type, intensity and duration of physical work required to complete the mission has a direct affect on increased metabolic heat production. Necessary clothing and equipment can also increase physiological strain from added loads, increased insulation and impact heat storage by inhibiting sweating or reducing circulation (Cheauvront, Goodman, Kenefick, Montain, & Sawka, 2008). Environmental factors such as solar load and high ambient temperatures frequently seen in areas of current military operations will impede heat transfer away from the body by convection, conduction or radiation. Clothing systems designed to protect against a health hazard (such as chemical substances) can cause decrements in health due while intended to be effective against the original occupational hazard (Levine, Sawka, & Gonzalez, 1998). High wind speeds can increase evaporative heat loss while high humidity will inhibit heat transfer.

The likelihood of immersion-related cold injuries is significantly influenced by exposure to wetness and water temperature (Roberts & Hamlet, 2001). Individual physiological factors including acclimation status, aerobic fitness, hydration and nutrition, skin disorders, illnesses, rest, and body fat can make Soldiers more susceptible to heat or cold injury and can make health risk analysis for a population more challenging (Roberts & Hamlet, 2001).

Heat strain can cause hyperthermia, increased sweating leading to dehydration and an increased heart rate, heat cramps, heat exhaustion and heat stroke which all lead to

decreased performance and have the potential to cause permanent effects or death (Gardner & Kark, 2001).

Cold temperatures can reduce blood flow to extremities and cooling of tissue resulting in decreased touch sensations, discomfort and loss of dexterity or fine motor skills which can directly impact a Soldier's mission performance. Extended exposure can lead to frostbite or permanent loss of the affected area. Excessive whole body cooling may cause decreases in mental and physical function, hypothermia and possibly death (Pozos & Danzl, 2001).

Both the U.S. Army and ACGIH use the Wet-Bulb Globe Temperature (WBGT) to determine the heat index and along with the intensity of work being performed, determine the duration a person can work in a hot environment to minimize the risk of heat injuries (ACGIH, 2010; TB MED 507, 2003). Sources of potential hazards in the acquisition of military equipment include shelters, vehicles and clothing systems. Shelters may induce temperature hazards if air ventilation, heating, or air conditioning is not adequate to maintain temperatures between 50 ^{o}F and 85 ^{o}F in extreme conditions (MIL-STD-1472F, 1999). Vehicle cab air conditioning and heating systems must meet performance criteria in MIL-STD-1472F whenever Soldiers occupy the vehicle for periods of greater than 30 minutes. Simulation of heat gains from equipment operation itself and consideration of the impacts of clothing are necessary during testing to accurately depict potential risks in typical use scenarios. Clothing must be evaluated if initial thermal manikin tests indicate a difference of greater than 0.1 water vapor permeability per thermal insulation unit (i_m/clo), a heat exchange coefficient, which indicates evaporative resistance (USARIEM TN08-01, 2008).

Data necessary to evaluate heating and cooling capabilities of military materiel are outlined in MIL-STD-1472F, U.S. Army Research Institute of Environmental Medicine (USARIEM) Technical Note TN09/02, USARIEM Technical Report TN 08-01, Test Operating Procedure (TOP) 2-2-816, and TOP 1-2-610 and WBGT readings are required in multiple zones after heat gains from equipment and clothing are simulated (MIL-STD-1472F, 1999; USARIEM TN09/02, 2009; USARIEM TN08-01, 2008; TOP 2-2-816, 1987; TOP 1-2-610, 1990).

MUSCULOSKELETAL TRAUMA – LIFT AND CARRY

Musculoskeletal disorders are caused or worsened by biomechanical stresses and trauma that can lead to pain involving muscles, tendons, and nerves. Occupational conditions that can contribute to musculoskeletal distress include repetitive motion, awkward or prolonged postures, excessive bending or twisting, pushing or pulling, continued arm elevation during overhead work, forceful exertions, excessive use of small muscles, mechanical compression, restrictive workstations, or improper seating (DA PAM 40-21, 2003). The manual handling of heavy components or equipment characteristic of military materiel can be a major cause of work-related musculoskeletal disorders. Injuries can be caused by direct trauma, a single overexertion or as a result of repetitive exertions. Loads carried by Soldiers have progressively risen possibly due to the weight of weapons and ammunition, improvements in protective gear and new communication and mobility technologies (Knapik, 2004).

OSHA has not set a limit for the private sector on the amount a person can lift or carry, so exposure standards fall under the General Duty Clause of the Occupational

Safety and Health Act of 1970, where the employer is required to furnish a place of employment free of recognized hazards that are likely to cause physical harm to employees (Occupational Safety and Health Act of 1970). A NIOSH mathematical model helps predict the risk of injury based on the weight lifted and any confounding factors such as posture, duration and frequency (NIOSH, 1994). The NIOSH criteria provides guidance to employers and developers, but are not legally enforceable.

In order to evaluate potential lift and carry health hazards, the USAPHC (Prov) requires information on the design weight of materiel, lifter interference with one another, lift frequency and height, load size, handles and grasp areas and gender of the user, as identified in MIL-STD 1472F.

MUSCULOSKELETAL TRAUMA – WHOLE BODY VIBRATION

Vibration hazards occur when a person comes in contact with a mechanical oscillating surface (AR 40-10, 2007). Exposure to whole body vibration (WBV) can occur from vehicles, heavy machinery, and vibrations transmitted through air or water. Segmental vibration is most common in the operation of hand-held tools or machinery. Personnel operating and riding in materiel may be subject to excessive WBV during prolonged use or movement even when operated at low speed or on improved terrain. Exposure to WBV can cause herniated and degenerative lumbar disc disease, low back pain, and possibly affect the gastrointestinal and cardiovascular systems (Alem, 2005).

Historically, medical assessors applied ISO 2631, which was adopted as ACGIH TLVs to determine risks of occupational exposure to vibrational hazards (International Standard, 2003). Military tactical vehicles may have met the published standards, but

Soldiers experienced medical effects that led to further research and the development of ISO 2631-5 applicable to military relevant scenarios (International Standard, 2004; Alem, 2005). Exposure guidelines aim to minimize risk of back pain and to allow personnel to operate materiel. Translational acceleration exposure limits for vertical vibration primarily in the 4-8 Hz range, and longitudinal or transverse in the 1-2 Hz range are based on the body's sensitivity to movement in those directions (USACHPPM, 1996). Guidelines also exist between 20 and 70 Hz for reduced comfort, which reduce the ability to read, eat, or write and fatigue-decreased proficiency levels that impair flying, driving or machinery operations (OSHA, 2008). The updated standard incorporates extended operations, continuous background vibration, and adverse conditions commonly encountered during the operation of military vehicles.

The WBV HHA refers combat developers to ISO 2631-1 and ISO 2631-5 for descriptions of testing requirements relative to the mission profile of the materiel being evaluated (International Standard, 2003; International Standard, 2004). It is also critical that USAPHC (Prov) receive the testing data in British Columbia Research Data File Structure format suitable for evaluation.

MUSCULOSKELETAL TRAUMA – SEGMENTAL VIBRATION

Segmental vibration focuses the vibrational hazard on a specific body part without transmitting it to the rest of the body. It can be associated with carpal tunnel syndrome, Reynaud's phenomenon, and can cause decreased muscle strength or chronic numbness in the affected area (NIOSH, 1997).

ACGIH provides TLVs for segmental vibration exposures (ACGIH, 2010). Adherence to exposure limits, deliberate rest periods and use of anti-vibration gloves for hand-arm tasks help reduce the risks associated with excessive segmental vibration.

MUSCULOSKELETAL TRAUMA – HEAD SUPPORTED MASS

Devices supported by a Soldier's head and neck such as night vision goggles (NVGs), chemical or oxygen masks, and communications equipment mounted on the helmet can shift the distribution of weight off the centerline, placing the user at risk of neck injury (Melzer, Brozoski, Letowski, Harding, & Rash, 2009). Retrospective studies of accidents involving U.S. Army aviators found they had a 45% greater chance of head or neck injury if they were wearing NVGs at the time of the incident (Shannon & Mason, 1998). There are currently no approved risk criteria for health hazards associated with head-supported mass. The U.S. Army Aeromedical Research Laboratory (USAARL) is working to develop guidelines as the understanding of neck injuries increases. Studies have shown that although mass location and distribution are important in design, higher acceleration and impact direction are dominating factors in neck movement and the resulting injuries (Manoogian, Kennedy, Wilson, Duma, & Alem, 2006). Until biomedical research can provide health hazard guidance, Soldiers are advised to stow or remove the materiel from the helmet if discomfort develops and when riding in a vehicle unless operational conditions dictate otherwise. The recommendation to materiel developers is to develop the helmet mounted device with the smallest possible mass, disperse the weight of devices attached to the helmet evenly over and close to the head and its gravitational axis, and provide posterior head/neck support if the materiel is used

when seated (Coakwell, Bloswick & Moser, 2004; Ivancevic & Beagley, 2004). Developers are also encouraged to coordinate directly with USAARL for data necessary to contribute to current research efforts.

DISCUSSION

The test requirements and health effects data contained in the standardized IHHAR elements reflect current research, regulatory standards, and DoD guidelines to enable mitigation of health risks and compliance with applicable safety and occupational health standards. It is essential for materiel developers to have the data requirements, health effects, and medical criteria defined early during the development process to allow them the opportunity to conduct proper tests to determine actual health risks and apply all facets of health risk mitigation recommendations.

Rapid advances in capability gap solutions and technology have led to a steadily increasing number of HHA requests. Standardization of IHHAR production will reduce the time necessary to provide HHA data requirements and initial recommendations to materiel developers, providing materiel developers more time to mitigate adverse health threats, and allow the HHA Program to manage the increased workload more efficiently and effectively (Kluchinsky Jr., Gross, Murnyak, McDevitt, & Spencer, 2004).

CHAPTER THREE: STATISTICAL ANALYSIS

INTRODUCTION

Early in its history, the HHA Program found it time consuming and difficult to reference or answer inquiries regarding historical assessments without a mechanism to catalog reports (Murnyak, 2002). During the *Materiel Solution Analysis* phase of the Defense Acquisition Process, the independent medical assessor reviews historical health hazard data on similar or predecessor systems (AR 40-10, 2007; Gross & Broadwater, 1993). With a steady increase in the number of HHA requests, the HHA Program sought an efficient way to archive reports (Kluchinsky Jr. et al, 2004; Murnyak, 2002). In 1982, HHA Reports were being tracked using a Lotus spreadsheet, followed by a dBase IV program in 1992, and finally a Windows-based Microsoft Access database in 1995 (Murnyak, 2002). The progression to the more sophisticated Access software allowed project officers the ability to enter RACs and recommendations into the electronic record and query report data without retreiving the paper copy (Murnyak, 2002). Neither the Lotus nor dBase IV programs had these capabilities. However, the migration of information introduces the potential for lost data and errors in reports. Furthermore, there is generally a period of training required for personnel to learn and become efficient with a new system. One specific aim of this study is to measure quality assurance and quality control aspects of the HI database to determine if it is at least 95% accurate when compared to the original reports.

The second specific aim of this study is to assess hazard specific HHA Reports provided to acquistion program managers for communication consistency and use of

current scientific or DoD accepted standards. The evaluation of the use of current standards were completed in Chapter 2 of this thesis. Evaluations for consistency of communication will determine how streamlining the process of providing data requirements to materiel developers will improve the HHA process. The third and final specific aim of this study is to analyze the HHA HI database to determine frequency and severity of health hazard types evaluated by the HHA Program. These three aims will answer the hypothesis whether ergonomic-related conditions with the potential to cause death, injury, illness, disability, or reduced job performance are the most common of the health hazard types evaluated by the HHA Program.

METHODS

Data fields within each record in Microsoft Access were compared to the electronic copy of the original report stored at the USAPHC (Prov) to determine the accuracy of the quality assurance and quality control aspects of the database. Data fields that have a primary impact on the overall classification of risk or classification of the materiel in question were selected for comparison. Identified hazard, severity, probability, RAC, customer identification, residual severity, residual probability, and residual RAC data fields were selected. The migration of the database to Microsoft Access in 1995 allowed for the entry of hazard severity, hazard probability, and RACs into a record. Entries migrated from previous databases did not include this information, so the evaluation of database accuracy was conducted on entries from the beginning of fiscal year (FY) 1995 (October 1, 1994) to the end of FY 2009 (September 30, 2009). There were 1,023 reports entered into the database during this period and all were used for the statistical

evaluations in this chapter. The HHA Program employed five administrative assistants responsible for entering HHA data during this period. Some variability is expected during periods where the administrative assistants are becoming familiar with the Access program and structure of the HHA Reports and during periods when the Program's operating procedures evolved. The low personnel turnover and relative ease of data entry in Microsoft Access lead to an assumption that the database is at least 97% accurate. In order to determine if the database is at least 95% accurate (confidence level, $1-\alpha = 0.95$), a sample size of 197 (n) records had to be evaluated. If the database was 97% accurate, evaluating a sample size of 197 would allow for a 0.02 margin of error, therefore allowing a statement of at least 95% accuracy. The database was intended to store and organize HHA data to conduct preliminary health risk research on earlier materiel, conduct trend analysis, and answer inquiries about systems to avoid the lengthy process of retrieving paper copies. In order to provide accurate data for any evaluation of trends or background research, it is essential that the database contain the same information as the HHAs provided to customers.

The 1,023 records were chronologically ordered by date of entry, then stratified by the dates of employment of the administrative assistant who entered them into the database. In addition to the five administrative assistants, entries were made during a period when the position remained vacant. Those records were treated as a separate stratum identical to those with an identified data entry person. Each strata was separated into a sample subset, chronologically ordered by date of entry (oldest to newest), and assigned a chronological administrative number. A random number generator was used to select the required number of records from each strata using the administrative number

identifiers. A representative number of records from each strata reflected the proportion of the total records that the administrative assistant entered into the database. This distribution of records was an effort to remove bias in accuracy due to the skills or experience of the different administrative assistants. The strata and proportions are outlined in Table 4. One administrative assistant entered the majority of records during the inclusion period while three of the six strata account for less than 5% of entries. The distribution of strata as well as the expected reasons for variability is what led to an assumption of high database accuracy. The comparative sizes of the strata also confirmed the need to distribute the sample by data entry personnel, rather than taking 197 from the population as a whole.

Table 4
Record Selection for Database Accuracy Evaluation

Strata	# of records entered	Proportion of total records	Proportion of sample n
1	4	< 0.01 (0.0039)	1
2	68	0.07	14
3	179	0.17	33
4	14	0.01	3
5	728	0.71	140
6	30	0.03	6
Totals	**1,023**	**1.00**	**197**

If a record was found to have an error in any one of the data fields, the entire record was determined to be inaccurate since the sample size necessary was 197, not the number of data fields in 197 records. Using the Wilson procedure without a correction for continuity, a proportion of accurate records and a 95% confidence interval for the proportion were determined (Newcombe, 1998). A rating scale was used to evaluate the historical HHA record, the standard, against the database record. If a record was determined to be inaccurate, it was given the value of 0, if accurate, it was assigned a

value of 1. The database was assumed to be at least 95% accurate, therefore a positively skewed distribution was expected, not a normal distribution of the binary variables. Using the commonly used Wald formula for a binomial confidence interval could produce limits above or below the actual limits of the scale (0 and 1) (Miller & Penfield, 2005). The Wilson procedure is not limited by an assumption of population normality and is less affected by the bounds of the scale used (Miller & Penfield, 2005).

To assess the consisentcy of historical reports, assessments were evaluated to see if the same data were requested, referenced, and described in the same manner using the standardized HHAs in Chapter 2 as the benchmark for comparison. A keyword-based search of the historical files on the public (P:) drive at USAPHC (Prov) was conducted for each hazard type. The results were sorted in chronological order, newest to oldest and the five most recent IHHARs for each hazard were selected. The cutoff for inclusion in consistency evaluations was set at 2004 in an attempt to account for previous personnel or administrative changes that would affect methods in the supporting programs, as well as updates to scientifically accepted standards. If less than five assessments have been conducted since 2004, only those meeting the inclusion criteria were used. If a particular health hazard had multiple facets, such as one that arises from weapon propellants, engine exhaust, or miscellaneous chemicals, more than five reports were included to ensure criteria from all potential hazard sources were evaluated.

The data requested in the initial HHA were compared to the data in the standardized document and determined to be the same or different. If different, they were assigned a value of 0, if the same, they were assigned a value of 1. Using the Wilson procedure without a correction for continuity, a proportion of consistency and a 95% confidence

interval for the proportion of consistency were calculated (Newcombe, 1998). The confidence interval obtained from the sample represents the proportion of the reports we expect to be consistent throughout the population of records. The samples were not randomly selected, the most recent HHAs were selected to represent the population since it was important to reflect the latest biomedical research data and regulatory health standards. This could potentially misrepresent the total population consistency estimate, as the evolution of regulatory standards would be expected to change the information that was required in the past. If a sample were drawn from the entire population, we would expect to see less consistent data than using the most current reports. Since the determination of the use of current standards was essential to the specific aim, the use of only the most recent reports was an accepted shortfall in any assumptions about the population.

A query of entries in the HI database determined the overall frequency counts of each hazard type in the 1,023 records. The hazard categories within the database differ slightly from the hazard categories in Chapter 2 and in the appendices due to differences or similarities in evaluation. Pathogenic organisms are not separated into bloodborne and waterborne hazards in the database. They are separated in the HHAs because of the differences in their health effects and criteria necessary for evaluation. Heat and cold stress hazards are separated in the database as there are instances where one, but not the other, is a potential health hazard. They are covered in a single IHHAR element because the methods for collecting the data are very similar and outlined in the same regulations. Also included in the statistical analysis are blunt and sharp trauma hazards, which are not covered in the IHHAR elements in Chapter 2. Nineteen health hazards categorized as

non-ionizing radiation (unknown) were omitted from analysis. During the analysis of database accuracy, each time this category was used, the original HHA identified one of the three electromagnetic energy health hazards. The assumption was made that the use of this category was most likely erroneous. Statistical analyses were conducted on hazard categories as they exist in the database. No attempt was made to segregate information to match the HHAs in Chapter 2. A relative frequency table was constructed to illustrate the overall occurrence of each hazard type within the database.

A cross tabular display was constructed to display the joint distribution of two hazards, then analyzed to determine any correlations between hazard types. The phi (ϕ) coefficient is a measure of association for two binary variables to determine the strength of any correlations between hazard types (Pett, 1997). To calculate the ϕ coefficient, the hazard types were placed in a 2 x 2 table with the data representing frequency of the hazards. The strength of the relationship is interpreted as values of ϕ close to 1 demonstrating a strong relationship and values below 0.30 demonstrating a very low or weak relationship, taking into account the sign to describe a positive or negative association (Pett, 1997).

A query from the HI database determined the frequency of each hazard severity, hazard probability and resulting RAC for each hazard type. Relative frequency tables were constructed for this data (Table 6).

RESULTS

The proportion of reports within the database that matched the HHA was 0.7056 (95% CI 0.6385, 0.7648). Of the 197 records evaluated, 139 were found to be accurate.

The most common error was an omission of the residual hazard severity, probability, and RAC from the database. The database allows for descriptive text to be entered and often the residual hazard information was written there, but not entered into the data fields. This occurred in 20 of the erroneous records. Omission of an entire hazard category from the database occurred nine times, and errors entering hazard severity, probability, or RAC occurred 10 times. RFR hazards in the HHAs were entered as ionizing radiation hazards in the database on 10 occasions. This error occurred in multiple strata and throughout the period covered, and cannot be attributed to one administrative assistant or to a familiarization period while the person learned the system. There were infrequent errors in the entry of customer data and an incorrect entry of hazard type to account for other inconsistencies. There was a period between 1996 and 1998 where a hazard severity of IV (negligible), hazard probability of D (unlikely), and RAC of 5 were entered as residual risk information in the database even if the HHA stated "no RAC is assigned" or before hazard mitigation strategies had been implemented. Further review of the reports and discussions with HHA Program project managers employed during this period found that the program automatically entered the lowest RAC and included a medical cost avoidance summary with each HHA to demonstrate the cost of effective risk mitigation. These 19 records were considered to be accurate for the purpose of this study. This practice was part of the Program's operating procedure and was considered to be correct at the time. There is expected to be some data variability with new personnel and the maturation of the risk assessment process and methods.

The proportion of consistency and 95% confidence interval of the database population for each health hazard are outlined below. The variable **n** represents the total

number of variables required for hazard evaluation in the reports being evaluated. For example, if a health hazard required four criteria for a complete assessment, and five initial HHAs were found in the historical inclusion period and used for evaluation n = 20. The variable **k** represents the number of variables in the historical reports that were consistent with the identified data requirements. The comparison matrixes used to determine the proportion of consistency contain the report title and date and define the criteria necessary for evaluation. They are attached as Appendixes Q through EE.

Table 5
Proportion of Consistency for Health Hazard Assessment Data Requirements

CATEGORY	# OF REPORTS	# OF CRITERIA	N	K	PROPORTION OF CONSISTENCY	95% CI
ACOUSTIC ENERGY - STEADY STATE NOISE	5	5	25	18	0.72	[0.5242, 0.8572]
ACOUSTIC ENERGY - IMPULSE NOISE	5	3	15	13	0.8667	[0.6212, 0.9627]
ACOUSTIC ENERGY - BLAST OVERPRESSURE	2	2	4	3	0.75	[0.3006, 0.9544]
BIOLOGICAL SUBSTANCES - PATHOGENIC ORGS (BLOODBORNE)	2	4	8	8	1	[0.6756, 1]
BIOLOGICAL SUBSTANCES - PATHOGENIC ORGS (WATERBORNE)	5	3	14[a]	9	0.6429	[0.3877, 0.8366]
BIOLOGICAL SUBSTANCES – SANITATION	6[b]	16	54[a]	40	0.7407	[0.6106, 0.8388]
CHEMICAL SUBSTANCES	8[b]	5	23[a]	23	1	[0.8569, 1]
OXYGEN DEFICIENCY	5	6	28[a]	17	0.6071	[0.4241, 0.7643]
RADIATION ENERGY - LASER/OPTICAL RADIATION	5	12	60	52	0.8667	[0.7584, 0.9309]

CATEGORY	# OF REPORTS	# OF CRITERIA	N	K	PROPORTION OF CONSISTENCY	95% CI
RADIATION ENERGY - RADIOFREQUENCY RADIATION	4	11	44	44	1	[0.9197, 1]
RADIATION ENERGY - IONIZING RADIATION	2	8	16	16	1	[0.8064, 1]
TEMPERATURE EXTREMES	5	4	20	15	0.75	[0.5313, 0.8881]
MUSCULOSKELETAL TRAUMA - LIFT AND CARRY	5	4	20	12	0.6	[0.3866, 0.7812]
MUSCULOSKELETAL TRAUMA - WHOLE BODY VIBRATION	5	2	10	10	1	[0.7225, 1]
MUSCULOSKELETAL TRAUMA - SEGMENTAL VIBRATION	2	5	10	10	1	[0.7225, 1]

[a]One or more criteria did not apply to the materiel being evaluated
[b]More reports queried to cover multiple facets of hazard exposure criteria

The relative frequencies of each hazard type within the 1,023 records included in the statistical evaluation are provided in Table 6. Hazards are identified by the number assigned in the table below during subsequent analyses.

Table 6
Frequency of Hazard Categories (All Report Types)

#	HAZARD	FREQUENCY	RELATIVE FREQUENCY
1	ACOUSTICAL ENERGY - STEADY STATE NOISE	451	0.1561
2	ACOUSTICAL ENERGY - IMPULSE NOISE	319	0.1104
3	ACOUSTICAL ENERGY - BLAST OVERPRESSURE	54	0.0187
4	BIOLOGICAL SUBSTANCES - PATHOGENIC ORGS	34	0.0118
5	BIOLOGICAL SUBSTANCES – SANITATION	43	0.0149
6	CHEMICAL SUBSTANCES	617	0.2136
7	OXYGEN DEFICIENCY	195	0.0675
8	RADIATION ENERGY - LASER/OPTICAL RADIATION	143	0.0495

#	HAZARD	FREQUENCY	RELATIVE FREQUENCY
9	RADIATION ENERGY - RADIOFREQUENCY RADIATION	168	0.0582
10	RADIATION ENERGY - IONIZING RADIATION	122	0.0422
11	TEMPERATURE EXTREMES – HEAT	266	0.0921
12	TEMPERATURE EXTREMES – COLD	161	0.0557
13	MUSCULOSKELETAL TRAUMA - LIFT AND CARRY	202	0.0699
14	MUSCULOSKELETAL TRAUMA - WHOLE BODY VIBRATION	109	0.0377
15	MUSCULOSKELETAL TRAUMA - SEGMENTAL VIBRATION	5	0.0017
16	MUSCULOSKELETAL TRAUMA - BLUNT TRAUMA	12	0.0041
17	MUSCULOSKELETAL TRAUMA - SHARP TRAUMA	3	0.0010
	TOTAL	2889	0.9948

The joint distribution of hazard categories is outlined in Table 7. These numbers illustrate the frequency of HHAs that contained the two identified hazards and are used to measure the ϕ coefficient and strength of relationship in Table 8. Any correlations above 0.30 are highlighted in bold.

Table 7
Joint Distribution of Hazard Categories (All Report Types)

	HAZARD #																
HAZARD #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	*	98	9	23	30	338	179	58	120	77	219	142	115	88	4	1	3
2		*	47	10	9	196	52	49	49	37	66	46	31	33	3	1	0
3			*	2	1	32	6	7	4	8	6	5	5	5	1	0	0
4				*	13	28	17	5	7	4	18	13	11	4	0	0	0
5					*	37	18	3	10	5	21	11	12	6	0	0	0
6						*	173	80	120	85	218	142	128	78	3	6	3
7							*	29	64	44	161	110	49	48	2	1	2
8								*	30	29	37	22	25	7	0	0	1
9									*	28	82	56	30	31	2	0	2
10										*	54	31	31	16	0	1	1
11											*	149	61	60	2	1	1
12												*	28	47	2	1	0
13													*	18	3	1	0
14														*	2	0	0
15															*	0	0
16																*	0
17																	*

Table 8
Phi (ϕ) Coefficient for Hazard Categories (All Report Types)

Tables 9 and 10 contain the frequency counts of each hazard severity, probability, and corresponding RAC. Table 9 consists of all HHAs done following data analysis that contain residual RACs while Table 10 contains only initial HHA data.

Table 9
Frequency of RAC (HHA)

RAC	HAZARD SEVERITY & PROBABILITY	TOTAL	RELATIVE FREQUENCY	RAC TOTAL	RELATIVE FREQUENCY OF RAC
1	1,A	2	>0.0001	161	0.0698
	1,B	10	0.0043		
	1,C	22	0.0095		
	2,A	60	0.0260		
	2,B	67	0.0291		
2	1,D	54	0.0234	701	0.3041
	2,C	635	0.2753		
	3,A	12	0.0052		
3	1,E	7	0.0030	786	0.3410
	2,D	375	0.1626		
	3,B	74	0.0321		
	3,C	320	0.1388		
	4,A	10	0.0043		
4	2,E	15	0.0065	295	0.1280
	3,D	279	0.1210		
	4,E	1	>0.0001		
5	3,D	1	>0.0001	362	0.1570
	3,E	11	0.0048		
	4,B	16	0.0069		
	4,C	114	0.0495		
	4,D	70	0.0303		
	4,E	150	0.0650		
TOTALS		2305		2305	

Table 10
Frequency of RAC (Initial HHA)

RAC	HAZARD SEVERITY & PROBABILITY	TOTAL	RELATIVE FREQUENCY	RAC TOTAL	RELATIVE FREQUENCY OF RAC
1	1,A			17	0.0483
	1,B				
	1,C	8	0.0227		
	2,A	2	0.0057		
	2,B	7	0.0199		
2	1,D	7	0.0199	144	0.4091
	2,C	136	0.3863		
	3,A	1	0.0028		
3	1,E	1	0.0028	116	0.3295

RAC	HAZARD SEVERITY & PROBABILITY	TOTAL	RELATIVE FREQUENCY	RAC TOTAL	RELATIVE FREQUENCY OF RAC
	2,D	51	0.1449		
	3,B	12	0.0341		
	3,C	52	0.1477		
	4,A				
	2,E	1	0.0028		
4	3,D	34	0.0966	35	0.0994
	4,E				
	3,D	3	0.0085		
	3,E	2	0.0057		
5	4,B	5	0.0142	40	0.1136
	4,C	13	0.0369		
	4,D	6	0.0170		
	4,E	11	0.0313		
TOTALS		352		352	

Tables 11 and 12 contain the frequency counts of hazard severity and probability for each individual health hazard. Table 11 is done following data analysis by USAPHC (Prov) and contains residual RAC information. Table 12 consists of initial HHA data.

Table 11
Hazard Frequency by Severity, Probability, and RAC (HHA)

Table 12
Hazard Frequency by Severity, Probability, and RAC (Initial)

DISCUSSION

The database did not meet the 95% accuracy objective. The errors cannot be attributed to only one individual administrative assistant as the inconsistencies were present throughout the six strata. The inconsistencies in the two largest strata were generally clustered towards the beginning of their specific inclusion periods, indicating anecdotal evidence there is a learning curve period while the administrative assistant gains familiarity with the HHA process, hazard types, and database operation. Conclusions regarding ionizing radiation and RFR hazards should be done with great caution due to the frequent errors in distinction between the two categories in the database.

Five criteria are necessary to evaluate risk for each of five steady-state noise HHAs resulting in 25 variables (n = 25). Eighteen variables were consistent throughout the historical reports (k = 18). The resulting proportion of consistency was 0.7200 (95% CI 0.5242, 0.8572). Half of the discrepancies occurred in one report that had a significantly different format than other HHAs. The report listed each potential hazard and data required for evaluation in table format, rather than in the text of the report, which significantly limited the amount of information that could be included. Less than 10 reports were formatted in this manner throughout the historical record. This record was not excluded from the sample as consistency of communication to the materiel developer was the key aspect of the database being evaluated and it met the inclusion criteria. The change in format could be a result of a change in operating procedures, but should not be expected to affect the content of the report. This reports inconsistencies demonstrate that changes in overall program procedures do have a measureable affect on the consistency

of reports, which was one rationale for the specific aim being investigated. The other half of the inconsistent data failed to specify that noise measurement data should be collected for all potential operational scenarios. If this data were omitted, it could lead to an incomplete assessment of risk. The comparison matrix used for consistency evaluation is attached as Appendix Q.

Impulse noise requires three criteria for evaluation, resulting in 15 variables in the last five HHAs (n = 15). Evaluation of the reports found 13 variables were requested consistently (k = 13). This leads to an overall proportion of consistency of 0.8667 (95% CI 0.6212, 0.9627) estimated for the database population. One report contained both discrepancies, the same report discussed previously that listed each potential hazard and data required for evaluation in table format, rather than in the text of the report, which significantly limited the amount of information that could be included. The comparison matrix is attached as Appendix R.

Only two items demonstrated potential blast overpressure health hazards. The input required for evaluation resulted in four variables for the two reports (n = 4). Three were consistent with the standardized document within the historical reports (k = 3). The resulting proportion of consistency is 0.75 (95% CI 0.3006, 0.9544). The low number of criteria necessary and low number of reports available for evaluation factor heavily into the wide confidence interval for the estimation of overall consistency within the population. The comparison matrix is attached as Appendix S.

During the five-year inclusion period, only two ambulance vehicles posed potential health risks from bloodborne pathogens and each had four general data requirements resulting in eight variables necessary for the two reports (n = 8). Both reports were

consistent and contained all necessary information (k = 8). This resulted in an estimated population proportion of consistency of 1.000 (95% CI 0.6756, 1.000). Although the observations were consistent, the width of the confidence interval accounts for the limited sample size available to represent the population. The comparison matrix is attached as Appendix T.

Only three items in the acquisitions process included water generation or treatment capabilities during the inclusion period. There were 14 total variables necessary for the three reports, not 15, as one system incorporated previously assessed materiel for water production but still required evaluation in extreme environments and water quality testing for the different operational scenario (n = 14). Nine variables were consistent in the historical reports (k = 9). The overall proportion of consistency for recent waterborne biological substance-related health hazards is 0.6429 (95% CI 0.3877, 0.8366). The confidence interval for the population estimates is wide in part because there were only three reports in the sample and five criteria necessary for each report. The comparison matrix used in evaluation is attached as Appendix U.

Six historical reports were queried in order to evaluate all facets of health hazards from sanitation-related biological organisms. The HHAs were compared for consistency in only those categories of sanitation (e.g. toilet, food service, potable water) for which the materiel potentially posed a health hazard. The historical records contained 54 variables necessary to complete HHAs on materiel in the acquisitions process (n = 54). Of those, 40 were consistent within the different reports (k = 40). The overall proportion of consistent reports for recent sanitation-related health hazards is 0.7404 (95% CI 0.6106, 0.8388). The comparison matrix is attached as Appendix V.

Consistency evaluations were performed on eight HHA Reports to ensure miscellaneous chemical, engine combustion and weapons combustion hazards were represented. This evaluation resulted in 23 variables necessary to evaluate the eight hazards (n = 23). All 23 were consistent with the standardized data requirements throughout the reports (k = 23). This results in a proportion of consistency of 1.000 (95% CI 0.8569, 1.000). The confidence interval is one of the narrowest of all health hazards due to the high number of variables in the sample and the proportion of those that were consistent. This narrower confidence interval indicates a more precise estimate of the consistency of all chemical substance HHAs in the entire database. The comparison matrix is attached as Appendix W.

For the previous five HHAs, there were 28 variables necessary to complete accurate oxygen deficiency health hazard evaluations (n = 28). Of those, 17 were consistently communicated to the materiel developer (k = 17). The resulting proportion of consistency is 0.6071 (95% CI 0.4241, 0.7643). The comparison matrix is attached as Appendix X.

The consolidated HHA determined there are 12 criteria needed to perform an accurate risk assessment on laser and optical radiation hazards. For the previous five reports, this resulted in 60 variables (n = 60). Of those, 52 were consistent throughout the reports (k = 52), leading to a proportion of consistency of 0.8667 (95% CI 0.7584, 0.9309). Eight variables were absent, half of them involving the location of the laser or optics on the equipment undergoing evaluation. All of the materiel missing the location variable were vehicles where location of the source could have an influence on the hazard effects. If the source was at a Soldier's eye level in a sitting or standing position while in

use, this could impact the frequency of exposure and the overall risk characterization. The comparison matrix is attached as Appendix Y.

In the five previous HHAs evaluating RFR hazards, there were 55 variables, 46 of which were consistent through the reports (n = 55, k = 46), resulting in an overall proportion of consistency of 0.8364 (95% CI 0.7174, 0.9115). All inconsistencies occurred in a single HHA performed on a signal-jamming device that operates in a different manner than the majority of radiofrequency emitting materiel. If that particular HHA is omitted from evaluation, all 44 variables were consistent (n = 44, k = 44) and the proportion of consistency is 1.00 (95% CI 0.9197, 1.000). In the standardization of the HHAs, it is accepted that there would be occasional materiel that could not be assessed by the data outlined in the document. This materiel would require an independent medical assessor review to tailor the data necessary to the operation of the materiel. The signal jamming device is an example of this situation. The comparison matrix is attached as Appendix Z.

Ionizing radiation data can be condensed into eight criteria to conduct a health risk assessment. Two pieces of materiel went through the acquisitions process during the inclusion period (n = 16). Both reports consistently communicated data requirements to the materiel developer (k = 16), resulting in a proportion of consistency of 1.000 (95% CI, 0.8064, 1.00). A possible reason for the high consistency of ionizing radiation HHAs could be due to the supporting programs compliance with strict NRC guidelines for the regulation of ionizing sources. The comparison matrix used for evaluation is attached as Appendix AA.

There are four criteria necessary to relay to the materiel developer to outline requirements to evaluate exposure to temperature-related health hazards, resulting in 20 variables for the HHAs evaluated for consistency (n = 20). Fifteen variables were consistent through the reports (k = 15), leading to a proportion of consistency of 0.75 (95% CI 0.8881, 0.9041). The comparison matrix is attached as Appendix BB.

The five most recent HHAs addressing musculoskeletal trauma from lift and carry hazards each contained four criteria for evaluation, the information contained in the worksheet, following design guidance in MIL-STD 1472F, determination of weight and lifting requirements and inclusion of limits and warnings on labels and in materiel manuals (n = 20). Of these variables, 12 were found to be consistent (k = 12). Four of the reports dated before May 2009 were missing the HHA lift analysis worksheet developed by USAPHC (Prov). This leads to an overall proportion of consistency of 0.6 (95% CI 0.3866, 0.7812). The comparison matrix is attached as Appendix CC.

Vibration-related hazards require two pieces of data for evaluation, resulting in 10 variables in the five historical records for consistency evaluation (n = 10). All 10 were consistent through the reports (k = 10) resulting in a proportion of consistency of 1 (95% CI 0.7225, 1). The comparison matrix is attached as Appendix DD.

Segmental vibration hazards are less common as only two pieces of materiel were evaluated since April 2005. Five criteria are necessary to complete a definitive HHA (n = 10), all of which were consistent (k = 10). The overall proportion of consistency is 1 (95% CI 0.7225, 1). The comparison matrix is attached as Appendix EE

The most frequent health hazard evaluated by the HHA Program was chemical substances, with a relative frequency in the population of 0.2136. Chemical substance

hazards are present in engine fluids and combustion products, batteries, weapons combustion products, cleaners, lubricants, and solvents. Regardless of the function, size, or classification of military materiel, one of two conditions are generally present, it needs a power source, such as a combustion engine or battery, or it involves munitions. Chemical substances were followed by steady-state noise with a relative frequency of 0.1561, and heat stress hazards with a frequency of 0.0921. The frequency of steady state noise hazards and heat stress hazards can also be a result of engine operation coupled with the material military systems are constructed of. Rugged metals will reflect sound as well as radiate and reflect environmental heat. The health hazards with the lowest relative frequency are sharp trauma (relative frequency 0.0010), segmental vibration (relative frequency 0.0017), and blunt trauma (relative frequency 0.0041). A hypothesis is that blunt and sharp hazards are infrequent because they are engineered out of designs due to immediately recognizable safety hazard potential. Segmental vibration occurs from the translation of movement to a single body part. The size and power of most military materiel with vibrational hazards may cause more exposures to be classified as WBV hazards than segmental hazards, contributing to the infrequency seen in the database.

The lowest value of ϕ that demonstrated a degree of association in the referenced literature was 0.30 (Pett, 1997). In order to explore the all of the potential relationships between hazard types, the same value was chosen for this study. The hazards with the values of ϕ that demonstrated the strongest relationship were heat and cold hazards (+0.66), followed by oxygen deficiency and heat stress hazards (+0.63), oxygen deficiency and cold stress hazards (+0.54), and oxygen deficiency and steady state noise

(+0.47). Steady state noise and heat stress hazards (+0.46), steady state noise and cold stress hazards (+0.38), and biological substance hazards from pathogenic organisms and sanitation (+0.31) also had values of ϕ that suggested correlation. Steady state noise hazards are a component of three of the top seven relationships identified by a strong ϕ coefficient. Steady state noise hazards are also the second most frequent health hazard evaluated by the HHA Program, so the frequency of correlations with other hazards is not unexpected. Heat and cold stress hazards demonstrated the strongest relationship with a ϕ coefficient of +0.66. It is reasonable to assume if materiel operates in conditions or environments with the potential for heat stress hazards, it would also be susceptible to cold stress hazards. The strength of this correlation is within expectations. Heat stress hazards were the fourth most frequent hazard in the database with a relative frequency of 0.0921. This is more common than cold hazards, with a relative frequency of 0.0557. The higher frequency of heat stress hazards could be attributed to the operation of the materiel itself adding to the environmental heat exposure. Oxygen deficiency hazards showed a relatively strong correlation with both heat and cold stress injuries (+0.63 and +0.54). The weakest relationship of the positively correlated health hazards with a ϕ of +0.31 was between pathogenic organisms and sanitation-related biological hazards. Like with heat and cold, this relationship is not entirely unexpected. Pathogenic organisms can be present where there is the potential for sanitation-related hazard conditions. However, this association is not stronger because not all sanitation-related hazard conditions have routine exposure to pathogenic organisms. For instance, exposure to pathogens in foodservice materiel could constitute a breakdown in food handling or cleaning requirements, an incident that is not covered by the HHA Program. The lowest

value of ϕ for any of the health hazard relationships was -0.17, with most negative values being between -0.01 and -0.03. The ϕ correlation coefficient does not suggest a strong negative correlation between any of the hazard types.

An IHHAR is completed on materiel that has not previously undergone health hazard evaluations, and independent medical assessors generally have not provided input on hazard mitigation for the specific materiel undergoing evaluation. They usually contain information on health risks and recommendations for hazard mitigation based upon similar or predecessor systems. Because of this, IHHARs could be expected to contain a greater frequency of RACs that reflect the potential for higher health risks. Evaluation of the frequency of each RAC determined that for initial IHHARs, a RAC of 2 had a relative frequency of 0.4091 and a RAC of 3 had a frequency of 0.3295. For HHA Reports done following testing and possibly implementation of hazard mitigating recommendations from initial HHAs, a RAC of 3 had a relative frequency of 0.3410 and a RAC of 2 had a frequency of 0.3041. This information demonstrates an overall decrease in the level of health hazard risk after independent medical assessors provide information on hazard mitigation and regulatory guidelines to materiel developers. The data sets are not paired so assumptions cannot be made for a direct cause and effect relationship between a lower RAC as a result of the HHA process.

Individual health hazards were evaluated to determine if there was a trend in risk classification frequency in the HHAs. This data is outlined in Table 11. Some health hazards exhibited high relative frequencies in a particular RAC. For example, steady state and impulse noise hazards were classified most frequently with a RAC of 2 (relative frequencies of RAC 2: 0.6038, 0.6726). Most military equipment is designed to

withstand extreme environments, is rugged in nature, and must be able to be decontaminated. For these reasons, it is often made out of strong materials that reflect sound rather than ones that absorb sound, which may contribute to the higher classification of health hazard risk from both types of noise hazards. Health hazards from RFR were most commonly classified with a RAC of 5 (relative frequency of RAC 5: 0.6541). The military generally uses low operating power communication systems close to Soldiers. These systems typically pose minimal health risks due to RFR. More powerful radar or satellite systems that could have more significant health effects are generally used further away from populated areas, potentially decreasing the probability of exposure and overall RAC. Musculoskeletal trauma hazards caused by lifting and carrying of objects were most commonly classified with a RAC of 3 (relative frequency of RAC 3: 0.5961). It is reasonable to assume that if a piece of equipment is heavy or awkward enough to meet health hazard criteria, it would have a significant probability and severity of musculoskeletal trauma injuries. The opposite could also influence why very little materiel is classified with a RAC of 1 or 2 due to musculoskeletal trauma. The point where equipment can no longer be lifted by manual power usually occurs before there is danger of meeting criteria for high hazard severity or probability outlined in Chapter 1. The most common RAC for laser and optical radiation hazards was 3 (relative frequency of RAC 3: 0.4650). This may be partially due to the susceptibility of the eye to this type of hazard. Excess exposure could lead to a significant health effect, the loss of vision, constituting a loss of a bodily system and therefore a higher risk. Heat stress hazards were most frequently assessed with a RAC of 2 or 3 (relative frequency of RAC 2: 0.4273, RAC 3: 0.3761, cumulative RAC 2 & 3: 0.8034). Large pieces of materiel

may contain significant sources of environmental heat contributors such as engines, generators or reduced ventilation in shelters designed for chemical warfare protection, increasing the likelihood and severity of exposure to heat stress.

CONCLUSION

The database accuracy is not as high as expected, with only a 0.7051 (95% CI 0.6385, 0.7648) proportion of accuracy. For this reason, caution should be exercised when interpreting and using definitive information from these statistical analyses. The HHA Program should consider implementing a procedure to review records when training new personnel on the use of the database. A project manager who is familiar with the hazards and the format of the HHA Reports should be considered for this task, as they would be able to identify and interpret information that may not be recognizable to a person unfamiliar with the process. This would increase the accuracy and result in a more definite statistical analysis of the data.

The standardization of HHA input will significantly improve the ability of the HHA Program to support the acquisitions process with more efficiency and reduce the burden on other supporting USAPHC (Prov) programs. The degree of improvement in the consistency of medial criteria, hazard effects, and guidance on test requirements communication varies with each specific hazard. The HHA Program plans to migrate the standardized HHAs to their website so health effects, medical criteria and data requirements are readily available to materiel developers and test personnel. This immediate access will allow the developers to incorporate preliminary health hazard considerations into the design and testing processes without waiting for a lengthy initial

evaluation by USAPHC (Prov). The desired outcome is for the acquisition program to use the data requirements to plan health effects testing to provide USAPHC (Prov) with the criteria necessary for more accurate HHAs. The current process of HHA development is time consuming. Data requirements and health recommendations often do not reach the developer before the materiel leaves the test and evaluation phase. Furthermore, health hazard testing is often disregarded due to cost and timeline constraints.

The incorporation of standardized HHAs into the USAPHC (Prov) website will not exempt HHA Program project managers and independent medical assessors of all initial health hazard responsibilities. There are instances where the standardized HHA data requirements may not cover atypical specifications of a particular piece of equipment. The materiel developer will have to work with the HHA project manager and independent medical assessors to ensure all potential health hazards are identified in those circumstances. Decreased workload provided by standardizing initial HHA input, should allow personnel from USAPHC (Prov) to be able to provide the tailored HHAs for unique situations to developers with ample time to incorporate the recommendations into design specifications as well as further test and evaluation plans.

The analyses quantify the data so overall trends in hazard severity, probability, and frequency can be reviewed or bring light to situations where particular facets should be explored further. Broad, concrete statements or assumptions cannot be made about the contributing factors and specific conditions that make some hazards are more frequent or more severe because of the vast range of materiel types supported by the HHA Program and database accuracy. This study can only speculate on possible contributing factors.

Future studies should pair specific initial and subsequent HHAs to draw a more definite conclusion regarding the impact of the HHA Programs contributions to the lowering of health hazard risks in military acquisitions.

The hypothesis of this study was to determine if ergonomic-related conditions were the most frequent health hazard evaluated by the HHA Program based on the frequency of private sector occupational evaluations (Bureau of Labor Statistics, 2009; Bureau of Labor Statistics, 2008) and frequent studies of occupational musculoskeletal injuries in military populations (Fabrizio, 2002; Feurstein, Berkowitz, & Peck Jr., 1997; Knapik, 2004; Lincoln et al, 2002; Manoogian et al, 2006; Shannon & Mason, 1998). Analysis of the HI database showed that ergonomic-related health hazards were not the most frequent of all hazards evaluated by the Program. Some ergonomic-related health hazards are still being refined, such as head supported mass, blast overpressure, and repetitive shock. As these hazards are better understood, identification of potential hazards should improve and the frequency of ergonomic-related health conditions in military populations may be reduced due to more effective risk mitigation efforts following better hazard analysis

CHAPTER FOUR: PUBLICATION MANUSCRIPT

Abstract:

Occupational illnesses and injuries degrade Soldier performance and reduce system effectiveness. The U.S. Army Health Hazard Assessment Program works to reduce health-related adverse consequences associated with fielding materiel by identifying and assessing health hazards during the acquisition process. Medical research, materiel development and materiel testing activities must work closely to ensure risks are identified and materiel is properly tested in order to quantify potential health hazards. Communication with materiel developers regarding health effects, medical criteria, and testing requirements early in the acquisition process enables integration of information into mitigation strategies, and influence the scope and type of testing for an optimal health hazard assessment. The ultimate goal is to eliminate health hazards from materiel systems while optimizing performance, meeting mission requirements, and minimizing total ownership costs.

Health hazards can create significant risks of death, injury, acute or chronic illness, and disability that can effect human performance and consequently, reduce overall system effectiveness (Gross & Broadwater, 1993). The Manpower, Personnel, and Integration (MANPRINT) program integrates these Soldier considerations into the Army Acquisition Process to enhance Solder-system design and optimize total system performance (AR 602-2, 2001). The U.S. Army Public Health Command (Provisional) (USAPHC (Prov)) established the Health Hazard Assessment (HHA) Program to identify and recommend mitigation of potential risks in materiel throughout the acquisitions

process that can adversely impact Soldier health and well-being (AR 40-10, 2007). The HHA Program is one of seven domains of MANPRINT including Manpower, Personnel, Training, System Safety, Soldier Survivability, and Human Factors Engineering. Each of these programs focuses on integrating Soldier considerations such as manpower structure, personnel aptitudes and training constraints into the Army Acquisitions Process to reduce total lifecycle costs, enhance Soldier-system design and optimize total system performance (AR 602-2, 2001).

The primary objective of the HHA Program is to identify and assess health hazards associated with the life cycle management of systems and provide recommendations to developers to eliminate or control the hazards (AR 40-10, 2007). The specific objectives outlined in Army Regulation 40-10 are to: "preserve and protect the health of individual Soldiers; reduce degradation of Soldier performance and enhance the system effectiveness; design out health hazards to eliminate the need for health hazard-based retrofits; reduce readiness deficiencies attributable to health hazards thereby reducing training or operational restrictions; reduce personnel compensation claims by eliminating or reducing injury or illness caused by health hazards associated with the use and maintenance of Army systems; and reduce environmental and occupational health hazards attributable to Army systems" (AR 40-10, 2007). Efforts of the HHA Program to identify, reduce, or eliminate the risk of exposure to health hazards from military materiel are quantifiable and directly affect individual health as military capabilities advance (Bratt, Kluchinsky Jr., Coady, Jordan, Jones, & Spencer, 2010).

Mitigation of health hazards is comprehensively integrated into acquisition design, testing, manufacturing, operation, maintenance, storage, demilitarization, and disposal

(AR 40-10, 2007). Early health risk assessments can provide recommendations for primary prevention strategies such as system design changes, elimination, product substitution, isolation, process modification, or enclosure that prevent exposure to the health risks (Bratt & Evenden, 1995). However, mission requirements do not always facilitate hazard free designs or conditions (Milz, Conrad, & Soule, 2003). Designs that reduce the hazard risk are preferable to safety devices that prevent unintentional use and as a result, possible exposure. Less favorable are warning devices, labels or alarms that warn the user of potential hazards as they occur. Administrative controls, including the development of work practices, training programs, and the use of personal protective equipment are the least preferred methods. These activities are the least successful in decreasing exposures because they rely on personnel to identify hazard opportunities and follow prescribed safety guidelines in order to be effective (AR 40-10, 2007). Medical research, materiel development, and materiel testing activities must work closely to ensure risks are identified and materiel is properly tested to quantify potential health hazards. Early HHA involvement helps ensure timely materiel delivery and incorporation of health hazard recommendations in development of system training, operational, and maintenance manuals (Bratt & Evenden, 1995).

The HHA contains a description of the potential hazard, data necessary for a health risk evaluation, initial recommendations to reduce hazard exposure under normal operating conditions, potential health effects to the operator, crew, or maintainer, and medical criteria of each health hazard. Early identification of specific hazard information and testing requirements can widen a system's trade space, while at the same time reducing potential occupational injuries and illnesses. Timely implementation of health

risk considerations will aid in optimizing total system performance, minimizing total ownership costs, and ensuring the system is built to accommodate the characteristics of the user population that will operate, maintain and support the system (DoDD 5000.01, 2007). Each of the health hazard types and their corresponding descriptions, health effects, medical criteria, test and information requirements, and references are outlined in the Table.

1 **TABLE 1. Health Hazards**

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
ACOUSTIC ENERGY – STEADY STATE NOISE	A pressure wave variation around the ambient atmospheric pressure exceeding 1 second in duration. Can be continuous, intermittent or fluctuating.	- Short term loss of hearing sensitivity - Permanent noise induced hearing loss	- ≥ 85 A-weighted decibel (dBA) time weighted average during 24 hour period	- Collect noise contour levels during each operating condition at all occupied positions, particularly in the 85 dBA contour	- Military Standard (MIL-STD) 1474D, Requirement 1 - Department of the Army Pamphlet (DA PAM) 40-501
ACOUSTIC ENERGY – IMPULSE NOISE	High-level, short duration pressure wave disturbance of less than 1 second at levels that can immediately cause acoustical trauma.	- Trauma to inner ear tissues - Immediate, permanent hearing loss	- Limit exposures to 140 dBA pressure levels during 24 hour period based upon hearing protection used - Additional allowances for large caliber artillery at 190 dBA	- Measure noise contours at defined distances and directions from the source, particularly at the 140 dBA level	- MIL-STD-1474D, Requirement 4 - DA PAM 40-501
ACOUSTIC ENERGY – BLAST OVERPRESSURE	Expanding gases compress surrounding air, generating a shock wave absorbed by the body.	- Disruption of structure or function of affected cells - Brain injuries - Pulmonary edema - Lung lacerations - Blood in	- Under development	- Collect live fire time and pressure data at weapon crew positions using approved blast test device	- U.S. Army Public Health Command (Provisional) (USAPHC (Prov)) Blast Overpressure (BOP) Program Guidance

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
		alveolar or abdominal cavities			
BIOLOGICAL SUBSTANCES – PATHOGENIC ORGANISMS (BLOODBORNE)	Potentially infectious materials present in blood and bodily fluids.	- Human Immunodeficiency Virus (HIV) - Hepatitis B virus (HBV) - Hepatitis C virus (HPC)	- Use of standard universal precautions - Defined infection control program - Segregation of regulated medical waste (RMW) - Material designed for decontamination - Incorporation of hazard information in training and operation manuals	- Provide scope, exposure control plan, method of compliance, vaccinations, training, record-keeping, and post-exposure evaluation plans - Provide designs, material composition, and RMW storage provisions	- Title 29 Code of Federal Regulations (CFR) Part 1910.1030
BIOLOGICAL SUBSTANCES – PATHOGENIC ORGANISMS (WATERBORNE)	Microbial pathogens such as bacteria, protozoans, viruses from excreta, toxic organic or inorganic substances from pollution can be inhaled, absorbed or ingested causing illness.	- Dehydration - Gastroenteritis - Skin or eye infections - Occupational asthma - Hepatitis	- Must meet physical and chemical characteristics for contaminants - Must limit direct exposure to water treatment chemicals and raw water sources - Prevent cross-contamination of raw and treated water	- Provide water treatment procedures, design specifications, materials and chemicals used - Provide administrative, design and engineering controls to prevent occupational exposure to pathogens - Conduct testing in extreme temperature	- Technical Bulletin Medical (TB MED) 577 - Field Manual (FM) 21-10 - FM 4-02.33 - U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM)TG 230

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
				conditions, under vibrational stress and in dusty environments - Provide water quality analysis results and intended usage for each product	
BIOLOGICAL SUBSTANCES – SANITATION	Ingestion, inhalation of, or contact with pathogenic microorganisms, toxins, or enzymes from unsanitary water supply, foodservice, waste management, laundry services, toilet and shower facilities, and pest control operations.	- Respiratory conditions - Hepatitis A - Gastrointestinal illnesses - Dermatitis - Acute or delayed chemical toxicity - Arthropod-borne diseases	- Material must be suitable for potable water contact as defined by the National Science Foundation (NSF) and Uniform Plumbing Code (UPC) - Water distribution, wastewater disposal systems and incinerators must support the intended population for the duration of the mission - Foodservice equipment must comply with requirements in TB MED 530 and be NSF or Underwriters Laboratory (UL) listed - Materiel must have condensate drainage systems and procedures to prevent accumulation of stagnant water - Toilet and shower facilities must be constructed so they do not leak, can be	- Provide specifications of final design, construction, cleaning, and maintenance requirements for foodservice equipment, shower and toilet facilities, condensate drainage systems, reverse osmosis elements, water distribution systems and storage tanks, and laundry facilities - Demonstrate any storage tanks, wastewater disposal systems or incinerators can support user	- TB MED 576 - TB MED 577 - Environmental Protection Agency (EPA) Cross Connection Control Manual 816-R-03-002 - American Water Works Association (AWWA) Recommended Practice for Backflow Prevention and Cross-Connection Control M14 - Title 40 CFR Part 243.200-1 - American National Standards Institute (ANSI) Standard A119.2 - TB MED 530

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
			thoroughly sanitized and maintained, contain provisions for hand washing - Toilet and shower facilities must accommodate the total number of personnel for mission duration - Laundry facilities must have countermeasures to prevent human exposure to soiled laundry and cross-contamination of clean laundry - All occupied structures and waste collection areas must include screens, air curtains or other pest exclusion devices	populations in all scenarios - Outline disinfection procedures for all materiel - Provide documentation of a cross-connection control survey in accordance with EPA and AWWA guidelines - Provide specifications of waste incinerator operating and maintenance procedures	- Title 29 CFR Part 1910.141 - FM 10-280 - TB MED 561 - Army Regulation (AR) 40-5 - Uniform Plumbing Code
CHEMICAL SUBSTANCES	Hazards exist from excessive concentrations of mists, gases, vapors, fumes or particulate matter that can be inhaled, ingested, absorbed, or injected and cause toxic effects	- Health outcomes depend on duration and level of exposure to specific chemicals ranging from decreased performance to death	- Exposure criteria follow most stringent of Occupational Safety and Health Administration (OSHA), American Council on Government Industrial Hygienists (ACGIH) Threshold Limit Values (TLV), or Federal agency with regulatory oversight of a workplace - Adhere to military-unique exposure guidelines for carbon monoxide, fog oil, and chemical warfare agents	- Collect information on combustion of any propellants and engine exhaust - Provide material safety data sheet (MSDS), chemical composition, purpose, and quantity of miscellaneous chemicals used in the maintenance or operation of	- Test Operations Procedure (TOP) 2-2-614 - DA PAM 40-8 - MIL-STD-1472F - Technical Report No. 9010 - USACHPPM TG 230

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
				materiel	
OXYGEN DEFICIENCY	Ventilation provides fresh and recalculated air to aid in the elimination of toxic chemicals, airborne dust and droplets. It also aids in controlling odors, temperature and humidity, and communicable diseases spread by airborne contaminants.	- Sick building syndrome - Asthma - Allergic rhinitis - Pneumonia - Influenza, acute respiratory infections, tuberculosis - Acute or chronic toxicity - Physiological effects due to lack of oxygen ranging from decreased coordination to death	- Temperature ranging from 68 – 76 degrees Fahrenheit (F) - Humidity < 60% - Ventilation rate of 15-20 cubic feet per minute (cfm) - Air velocity should be adjustable from zero to 400 feet per minute at vehicle occupants head - Toxic substances should not exceed limits specified by OSHA, ACGIH or other regulatory agency - Confined spaces with oxygen levels below 19.5% or above 23.5%, with limited means of egress, potential to engulf an entrant, or containing another health or safety hazard must follow OSHA guidelines	- Provide ventilation data including maximum personnel occupancy, area volume, total fresh and recirculated air rates for all scenarios	- MIL-STD-1472F - TOP 1-2-610 - Title 29 CFR Part 1910 - American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 62
RADIATION ENERGY – OPTICAL RADIATION	Laser and optical radiation hazards exist along a beam path of concentrated wavelengths of light.	- Damage to retina or cornea ranging from simple reddening to permanent physical damage and visual detriments - Skin exposure can result in mild reddening to	- Exposures at 400-1,400 nanometers (nm) require very little energy to cause damage - Wavelengths above 700 nm are invisible and have a maximum 10 second exposure limit - Classification, hazard distance, and optical density calculations are calculated for each wavelength and	- Provide certification using the Federal laser standard for commercial systems - Provide information on the source, operating modes, primary use, transmitter	- Title 21 CFR Part 1040 - MIL-STD-1425A - TB MED 524 - DA PAM 40-11

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
		blistering or charring	exposure scenario	wavelength, maximum output power, maximum energy per pulse, pulse width at ½ power points, maximum pulse repetition frequency, distance from aperture to waist, total pointing error in μrad, exit beam diameter at 1/e points, beam divergence, at 1/e points, beam distribution, beam profile, laser medium, safety features, and day view optics for military-unique sources	
RADIATION ENERGY – RADIO FREQUENCY RADIATION	Non-ionizing portion of the electromagnetic energy spectrum between 3 kilohertz (kHz) to 300 gigahertz (GHz).	- Cell temperature increases leading to redness, tissue damage, cataracts, and burns - Shocks stimulating nerves or muscles that can affect	- 3-100 kHz maximum permissible exposures (MPE) for induced currents range between 0.50f and 2.00f for 0.2 seconds depending on contact area - 0.1-110 MHz MPEs for induced currents range between 50 and 200 for 360 seconds depending on contact	- Provide list of radiofrequency sources, frequency, peak and average power output, pulse repetition frequency, pulse width, duty cycle, antenna type, size and gain,	- DA PAM 40-11 - DD FORM 1494 - AR 385-10 - ANSI/Institute of Electrical and Electronics Engineers (IEEE) C95.1-2005 - ANSI/IEEE C95.6

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
		brain or cardiac function	area - MPEs for adverse heating are dependent upon frequency and body composition	transmission line length and losses, and the location of the source on the equipment/materiel	- DA PAM 385-24 - TB MED 523 MIL-STD-464 - Title 10 CFR Part 20
RADIATION ENERGY – IONIZING RADIATION	Ionizing radiation consists of particles or electromagnetic energy capable of detaching electrons from atoms or molecules when passing through matter.	- Increased risk of cancer - Fertility or genetic effects - Can effect growth or development of cells	- Effective dose not exceeding 50 millisievert (mSv) per year - Occupational doses exceeding 5 mSv per year require personal dosimeter monitoring	- Provide operating parameters, radiation output, and system certification for x-ray devices - Provide details of radioactive material including isotope(s), chemical or physical form, amount of isotope in each system, whether source is sealed, unsealed, plated, or foil - Provide operating parameters, neutron emission rate, and average energy emitted for neutron sources - Provide verification that x-ray devices meet applicable Title 10 CFR or 21 CFR requirements	- AR 40-5 - Title 10 CFR Part 20 - DA PAM 385-24 - AR 358-10 - ANSI N43.2-2008 - ANSI N43.17-2002 - DA PAM 40-18

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
				- Verification that radioactive sources meet ANSI standards requirements - Provide Nuclear Regulatory Commission license or DA authorization for the material or device - Outline special operational procedures for production and deployment - Provide storage, use, maintenance, disposal, and special handling requirements	
TEMPERATURE EXTREMES	Interactions between mission, environmental factors, and physiological factors that affect metabolic heat production.	- Hyperthermia - Increased sweating, dehydration, and increased heart rate - Heat cramps - Heat exhaustion - Heat stroke - Physical or cognitive performance	- Enclosed spaces should be maintained between 50 – 85 degrees F - Vehicle cabs must maintain temperatures between 50 – 85 degrees F if occupied for longer than 30 minutes - Temperatures at head and floor level should not differ by more than 10 degrees F - Air discharges should not be directed on operator or crew	- Provide Wet Bulb Globe Temperature (WBGT) data at occupant, head, chest and foot positions - Tests should outline materials heating and cooling system in all operational scenarios	- MIL-STD-1472F - TOP 2-2-816 - TOP 1-2-610 - AR 70-38 - TB MED 507 - ACGIH TLVs - International Standards Organization (ISO) Standard 11092 - U.S. Army Research Institute

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
		decrements - Discomfort - Loss of dexterity or fine motor skills - Frostbite - Hypothermia - Death	members - Additional evaluation of clothing is required if thermal manikin tests indicate a difference of ≥ 0.1 in water vapor permeability per thermal insulation unit (i_m/clo)	- Simulate all heat gains - For clothing, provide dry bulb temperature, relative humidity, wind speed, mean radiant temperature, altitude, work rate, acclimatization days, dehydration, uniform, height and weight of subject - Provide ambient temperature and humidity of enclosed spaces at boundary surfaces (roof, floor, walls) and zones of interest (head, chest, knee/thigh, and foot), air flow from openings, and heat sources for 24 hour time period	of Environmental Medicine (USARIEM) Technical Report No. TN08-01 - USARIEM Technical Report No. TN09/02
MUSCULOSKELETAL TRAUMA – LIFT AND CARRY	Biomechanical stresses and trauma such as repetitive motion, awkward or prolonged	- Pain, tears, sprains, impairment, or abnormalities involving muscles, nerves, joints, or tendons	- National Institute for Occupational Safety and Health (NIOSH) lifting index (LI) > 1.0 indicates increased risk for musculoskeletal injury	- Provide design weight of materiel, lifter interference with one another, lift frequency and height, load size, handles and grasp	- MIL-STD-1472F paragraph 5.9.11 - NIOSH Publication No. 94-110

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
	postures, excessive bending or twisting, pushing or pulling, continued arm elevation during overhead work, forceful exertions, excessive use of small muscles, mechanical compression, restrictive workstations, or improper seating.	- Low back pain		areas, and gender of the user	
MUSCULOSKELETAL TRAUMA – WHOLE BODY VIBRATION	Contact with a mechanical oscillating surface that transmits vibration to the body.	- Herniated and degenerative lumbar disc disease - Low back pain - Gastrointestinal disruption - Cardiovascular system effects - Impairment of visual tasks	- Avoid exposure to frequencies below 20 hertz (Hz) - Minimize exposure to vibration between 20 – 70 Hz	- Collect acceleration data over a range of speeds and terrains for all occupied positions - Store data in British Columbia research data file structure for evaluation	- International Standards Organization (ISO) 2631-1 - ISO 2631-5 - MIL-STD-1472F
MUSCULOSKELETAL TRAUMA – SEGMENTAL VIBRATION	Focus of a vibrational hazard on a specific body	- Carpal tunnel syndrome - Reynaud's phenomenon	- Do not exceed ACGIH TLVs for total daily exposure (4 meters per second squared (m/s^2) = 4 – 8 hours, 6 m/s^2 =	- Provide the dominant, frequency-weighted root-	- ACGIH TLV for Chemical Substances, Physical Agents,

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
	part without transmitting it to the rest of the body.	- Decreased muscle strength - Chronic numbness	2-4 hours, 8 m/s^2 = 1-2 hours, 12 m/s^2 = < 1 hour)	mean-square, component acceleration and exposure time	and Biological Exposure Indices
MUSCULOSKELETAL TRAUMA – HEAD SUPPORTED MASS	Devices supported by head and neck can shift the distribution of weight off the centerline.	- Acute and chronic neck injury - Degraded performance	- For reference only, utilize the automotive industry thresholds for likelihood of significant injury: forces in x and y axis ± 697 pounds, force in z axis ± 900 pounds, flexion moment in y axis + 1681 inch-pounds, and extension moment in y axis - 505 inch-pounds	- Coordinate with the U.S. Army Aeromedical Research Laboratory to capture center of mass, head acceleration and angular velocity data, neck forces and moments at C1 at C7/T1 vertebrae, thorax accelerations at C7/T1 and sternum, lumbar forces and moments at vertebrae L5	- Under development
MUSCULOSKELETAL TRAUMA – RECOIL	Reactive force directed backwards following weapons fire.	- Range of motion limitations - Decreases in muscle strength - Soft tissue contusions and lacerations - Pain	- Recoil energy can not exceed 60 foot pounds (ft-lbs) for weapons - Unlimited firing of weapons with less than 15 ft-lbs - 200 rounds per day per person allowed for weapons with 15 – 30 ft-lbs of recoil energy - 100 rounds per day per person allowed for weapons	- Weight of the weapon - Weight of the propellant - Weight of the round - Recoil impulse - Recoil energy - Recoil velocity	- TOP 3-2-504 - USARIEM Technical Report No. T04-05

HAZARD TYPE	DESCRIPTION	HEALTH EFFECTS	MEDICAL CRITERIA	TEST AND INFORMATION REQUIREMENTS	REFERENCES
			with 30-45 ft-lbs of recoil energy - 25 rounds per day per person allowed for weapons with 45-60 ft-lbs of recoil energy		
MUSCULOSKELETAL TRAUMA – ACCELERATION DECELERATION	Injury resulting from the collision between a body part and another object or body part when both are in motion as an abrupt tensile stress imposed on the body.	- Muscle and soft tissue injuries - Whiplash - Anatomical trauma - Closed head injuries	- Estimated limits of tolerability are approximately 25 G for 0.1 second along forward lateral axis, 15 G for 0.1 second along backwards lateral axis	- Magnitude and duration of the applied force - Rate of onset of applied force - Direction of force - Site of application	- Under development
MUSCULOSKELETAL TRAUMA – BLUNT TRAUMA	Injury from sustained pressure on areas where nerves and bones run superficially under the skin.	- Fractures - Numbness and swelling - Loss of use of body part	- Under development	- Location of sustained pressure points - Weight applied to each location	- Under development
MUSCULOSKELETAL TRAUMA – SHARP TRAUMA	Injury sustained from pointed or focused projections.	- Damage to eye - Lacerations or fractures - Death	- Under development	- Eliminate objects that protrude from materiel	- Under development

The information contained in the HHAs reflect current research, regulatory standards and Department of Defense guidelines for mitigation of health risks and compliance with safety and occupational health standards. Improved availability of this information allows consideration of health effects during the design of materiel, and will enable planning, programming, budgeting, and execution of resources by materiel developers and acquisition managers for appropriate testing to ensure accurate assessment of health risks. The HHA recommendations can then be considered for implementation during the risk management process, while considering their effects on cost, performance, and scheduling of the acquisition program.

The HHA Program is also expanding the Medical Cost Avoidance Model (MCAM) to define the medical and lost time costs associated with occupational injuries avoidable through implementing effective health risk mitigation strategies (Kluchinsky Jr., Gross, Murnyak, McDevitt, & Spencer, 2004). This model will assist materiel developers and acquisition program managers in establishing health hazard mitigation priorities that have the greatest financial impact on Soldier health and well being (Bratt et al, 2010).

The Army is making great strides to ensure health hazards are considered and addressed during the acquisition process while accommodating mission, capabilities, and resources. The HHA Program helps materiel developers incorporate health hazard mitigation, military standards, and rules and regulations into the acquisition process, potentially reducing health care costs, improving readiness, and avoiding the costly retrofits on future systems. Advances in occupational health, improvements to the human-system interface and advancing technologies create both enhancements and challenges to the classification of traditional health hazards. Reductions in health hazard

effects from current materiel will have significant long-term impacts on the reduction of health care costs, improved readiness, and the avoidance of costly retrofits on future systems. Materiel developers and acquisition program managers may use the health hazard information outlined in the Table to tailor test plans to include data collection requirements unique to the HHA Program. This effort will result in a more accurate, precise, and timely assessment of health hazards associated with the operation, testing, and maintenance of materiel.

References:

Army Regulation (AR) 40-10. (2007). *Health Hazard Assessment Program in Support of the Army Acquisition Process.* Washington DC: Headquarters Department of the Army.
AR 602-2. (2001). *MANPRINT in the System Acquistion Process.* Washington, DC: Headquarters, Department of the Army.

Army Regulation (AR) 70-1. (2003). *Army Aquisition Policy.* Washington DC: Headquarters Department of the Army.

Blast Overpressure (BOP) Program Guidance. (2005 1-December). BOP Program Guidance. *Program Guidance for Blast Overpressure Analysis* , 1-8. Aberdeen Proving Ground, MD: USACHPPM.

Bratt, G., & Evenden, J. (1995). *U.S. Army Health Hazard Assessment Program Strategy.* U.S. Army Office of the Surgeon General. McLean, VA: Logistics Management Institute.

Bratt, G., Kluchinsky Jr., T., Coady, P., Jordan, N., Jones, B., & Spencer, C. (2010). The Army Health Hazard Assessment Program's Medical Cost-Avoidance Model. *American Journal of Preventive Medicine , 38* (1S), S34-S41.

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Gross, R., & Broadwater, W. (1993). Health Hazard Assessments. In D. G. Deeter (Ed.), *Occupational Health: The Soldier and the Industrial Base* (Vol. III, pp. 165-195). Washington DC: The Borden Institute.

Kluchinsky Jr., T., Gross, R., Murnyak, G., McDevitt, W., & Spencer, C. (2004 January-March). The U.S. Army's HHA Program: Past, Present, and Future. *Army Medical Department Journal* , 28-35.

Milz, S., Conrad, R., & Soule, R. (2003). Principles of Evaluating Worker Exposure. In S. DiNardi (Ed.), *The Occupational Environment: Its Evaluation, Control, and Management* (pp. 114-127). Fairfax, VA: American Industrial Hygiene Association.

CHAPTER FIVE: CONCLUSION

This study's hypothesis evaluated the U.S. Army's HI database to determine if ergonomic-related conditions with the potential to cause death, injury, disability, or reduced job performance were the most common health hazards evaluated by the HHA Program. Ergonomic-related conditions comprise a large majority of military outpatient encounters but were not the most common of the health hazard types evaluated by the HHA Program (Fabrizio, 2002; Feurstein, Berkowitz, & Peck Jr., 1997; Knapik, 2004; Lincoln et al, 2002; Manoogian et al, 2006; Shannon & Mason, 1998). This lower than expected frequency could be caused by poor understanding and classification of ergonomic-related health hazards. Efforts are underway to improve some of these health risk classifications, specifically in the instances of head-supported mass, repetitive shock and blast overpressure. Current patient encounter databases do not allow injury or illness classification to be captured systematically. The high frequency of musculoskeletal injuries seen in military populations may be due to accidents or injuries not caused by an occupational exposure to a health hazard. The DMSS and CHCS patient encounter databases should be modified to require a medical provider to distinguish between an illness or injury resulting from occupational exposure, a work-related accident or mishap, or a physical training injury. There is currently no way to attribute a medical condition to an occupational exposure to a health hazard and distinguish it from other incidents. Quantification of potential negative health effects is the first step in fully determining the effectiveness of the HHA Program at reducing health risk outcomes.

The first specific aim determined frequency and severity of health hazard types and any trends in relationships between individual hazards. The most frequently encountered health hazards in the HHA Program were chemical substances, steady-state noise and heat stress hazards. A possible contribution to the frequency of these hazards could be the presence of combustion engines in many materiel systems. Steady-state noise and heat stress hazards were commonly identified in the assessment of military materiel. The frequency of these hazards could be attributed to the presence of combustion engines aided by the durable physical characteristics of most materiel, which can reflect sound waves and environmental heat. The three health hazards with the lowest overall frequencies in the database were all ergonomic-related, blunt and sharp trauma, and segmental vibration. Trauma risk assessment infrequencies could be a result of physical safety hazards being easier to recognize and mitigate early in the design process. The relatively large size and power of military materiel could pose a greater risk of exposure to WBV hazards rather than segmental vibration. This would explain the relatively low frequency of the segmental vibration risk even though most materiel demonstrates a vibration hazard.

The analysis of associations between specific hazard types did not reveal any unexpected relationships. One of the most frequent health hazards, steady state noise, was present in three of the top seven significant correlations. Steady state noise hazards demonstrated moderately strong relationships with oxygen deficiency ($\phi = +0.47$), heat stress hazards ($\phi = +0.46$) and cold stress hazards ($\phi = +0.38$). Relationships were also demonstrated between heat and cold hazards ($\phi = +0.63$), and pathogenic organisms and

sanitation hazards (ϕ = +0.31). None of the correlations suggested a strong negative relationship between any of the health hazards.

Initial HHAs are conducted on materiel to provide recommendations for health hazard mitigation; this is usually the first time the materiel developer receives information on potential health risks. Initial HHAs could be expected to contain lower RACs (higher risks) than subsequent HHAs performed on the same materiel as the input from the medical assessor would be expected to reduce the severity and probability of health risks. Analysis of assessments showed that initial HHAs had a higher frequency of a RAC of 2 (0.4091) than a RAC of 3 (0.3295) while HHAs conducted following testing and implementation of risk reduction recommendations, a RAC of 3 was more common than a RAC of 2 (0.3410, 0.3041). This demonstrates that about 10% of the RAC 2 health hazards present in initial reports were mitigated following HHA Program involvement. Subsequent increases in RACs 3-5 in residual HHA Reports confirm this. These analyses were done on the population subsets, so only indicate the overall trends in the database, and should not be attributed as a direct effect of the HHA process. Further studies on the contributions and effectiveness of the recommendations provided by the HHA Program to risk reduction should conduct paired analyses of initial HHAs with HHAs done after hazard mitigation to explore the limitation of assumptions in this study. This information could further elucidate whether health risk mitigation efforts were successful in reducing specific hazard severities and probabilities, thereby minimizing occupational health hazards to individuals at risk for exposure rather than relating a general overall trend as this study demonstrated.

The second specific aim evaluated the consistency of communication and whether the data requirements, initial recommendations, health effects and medical criteria reflected current scientific knowledge. The information contained in the IHAARs reflect current research, regulatory standards and DoD guidelines for mitigation of health risks and compliance with safety and occupational health standards. The standardization of HHA input will have various degrees of impact on the consistency of reports for individual health hazards. The overall benefit will be an increase in the HHA Program's ability to support the acquisition process by providing ready access to accurate data essential to the acquisition process. Improved availability of this information will allow for consideration of health effects during the design of materiel, and will afford the materiel developer time to conduct appropriate testing to ensure an accurate health risk assessment. The HHA recommendations can then be implemented within cost and timeline constraints.

The last specific aim evaluated a sample of the database for accuracy. The accuracy of the HHA HI database was not as high as anticipated. It was expected that the database would be 95% accurate when compared to the paper reports provided to materiel developers. The actual proportion of accuracy was only 0.7051 (95% CI 0.6385, 0.7648). Errors occurred throughout the inclusion period and can possibly be attributed to a period where the administrative assistant responsible for entering data lacked familiarity with the database and HHA process. Improvements to accuracy could be realized with additional review of records as new employees are trained on database procedures. The level of accuracy is a limitation when making concrete statements regarding the effectiveness of the HHA Program at lowering risk from occupational health hazards.

Historical examples have demonstrated how the lack of medical reviews or health risk considerations has led to an increase in occupational illnesses and injuries (Gross & Broadwater, 1993). Advances in occupational health, improvements to the human-system interface and advancing technologies create both challenges and enhancements to the classification of traditional health hazards. However, reductions in health hazard effects from today's materiel will have significant long-term impacts on the reduction of health care costs, improved readiness, and the avoidance of costly retrofits on future systems. The Army is making great strides to ensure health hazards are considered and addressed in the acquisitions process while considering the mission, needs, available time and resources. This begins with effectively communicating special military standards, rules and regulations are communicated to the materiel developer.

The HHA Program is also working on further developments of the Medical Cost Avoidance Model (MCAM) to define the financial implications of occupational injuries potentially avoided by effective health risk mitigation (Kluchinsky Jr., Gross, Murnyak, McDevitt, & Spencer, 2004). This model will assist the materiel developer in establishing health hazard mitigation priorities that have the greatest financial impact on Soldier health and well-being (Bratt, Kluchinsky Jr., Coady, Jordan, Jones, & Spencer, 2010). A more robust and accurate MCAM would be enhanced by the ability to distinguish occupational exposure injuries and illnesses from other workplace mishaps.

The efforts of the HHA Program at identifying and eliminating or reducing the risk of exposure to health hazards from military materiel are quantifiable and have a direct effect on protecting the current health of individuals and as our military capabilities advance.

APPENDIX A: ACOUSTIC ENERGY (STEADY-STATE NOISE) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Collect steady-state noise data in accordance with Military Standard (MIL-STD) 1474D, Requirement 1 at positions occupied by operators, passengers, crewmembers or maintenance personnel, at noise sources and around the equipment for each noise-unique operating condition (reference 1). Provide the data, including a detailed use scenario, to the U.S. Army Public Health Command (Provisional) to support the completion of a definitive HHA. Special attention must be made to collect appropriate data to determine the 85-decibels, A-weighted (dBA), steady state noise contour. Contact the Hearing Conservation Program if assistance is needed with data collection or in establishing noise design goals to minimize adverse health effects.

(2) Eliminate steady-state noise associated with materiel and support design to the maximum extent feasible to reduce the reliance upon hearing protection devices for hearing conservation, reduce aural signatures and reduce the range of detectability.

(3) All personnel exposed to hazardous noise must wear hearing protective devices (HPDs). The Department of the Army Pamphlet (DA PAM) 40-501 lists HPDs approved for Army use (reference 3). HPDs must be fitted for size by properly trained personnel (if pre-formed earplugs or helmets); adequately maintained; and properly worn by the wearer. Double hearing protection consists of: approved earplugs in combination with a noise muff or noise-attenuating helmet.

Health effects.

Elevated sound levels can cause trauma to the eardrum, to the bones of the middle ear that amplify sound, or to the hairs of the inner ear that convert sound energy into a signal that travels to the brain. Overstimulation can lead to a temporary reduction in hearing or ringing in the ears, and the cells can recover if the exposure is not severe. Damage to the hair cells from repeated exposure over a period of time will result in permanent noise-induced hearing loss. Excessive noise can be continuous and not vary with time, intermittent if broken by periods of very low noise levels, or fluctuating if the sound pressure varies over a wide range.

Medical criteria.

(1) A steady-state noise level of 85 dBA or greater is considered hazardous (reference 1 and 2). This limit assumes no more than 8 hours per day of exposure to high noise levels. Prolonged unprotected exposure to hazardous noise levels will cause loss of hearing.

(2) For exposures exceeding 8 hours per day, noise levels below 85 dBA may be hazardous (reference 2). An exposure level above 80 dBA is considered hazardous if the duration of exposure is 24 hours.

(3) For long term continuous (24 hours per day) exposures, levels up to 75 dBA are not considered hazardous. However, if personnel can be exposed to high levels (above 85 dBA) during the duty day then they should be provided with the means of "resting" their ears for at least 8 hours with at-ear exposure below 65 dBA (reference 4).

References.

(1) Military Standard (MIL-STD) 1474D, Department of Defense Design Criteria Standard: Noise Limits, 12 Feb 97.

(2) Army Regulation (AR) 40-5, Preventive Medicine, 22 Jul 05.

(3) Department of the Army Pamphlet (DA PAM) 40-501, Hearing Conservation Program, 10 Dec 98.

(4) U.S. Department of Health, Education, and Welfare, National Institute for Safety and Heath, subject: Criteria for a recommended standard, occupational exposure to noise, 1972.

APPENDIX B: ACOUSTIC ENERTY (IMPULSE NOISE) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Eliminate impulse noise associated with materiel and support design to the maximum extent feasible to reduce the reliance upon hearing protection devices for hearing conservation, reduce aural signatures and reduce the range of detectability.

(2) Collect impulse noise data in accordance with Military Standard (MIL-STD) 1474D, Requirement 4 at all crew, passenger, and user positions and provide to this Center to support the completion of a definitive HHA (reference 1). Special attention must be made to collect appropriate data to determine the 140 dB noise contour.

(3) All personnel exposed to hazardous noise must wear hearing protective devices (HPDs). Department of the Army Pamphlet (DA PAM) 40-501 lists HPDs approved for Army use (reference 2). HPDs must be fitted for size by properly trained personnel (if pre-formed earplugs or helmets); adequately maintained; and properly worn by the wearer.

(4) Double hearing protection consists of: approved earplugs in combination with a noise muff or noise-attenuating helmet.

Health effects.

Elevated sound levels can cause trauma to the eardrum, to the bones of the middle ear that amplify sound, or to the hairs of the inner ear that convert sound energy into a signal that travels to the brain. Acoustic trauma from high-level, short duration noise exposure can stretch the tissues of the inner ear beyond their elastic limits, causing immediate, permanent hearing loss. This can also be accompanied by ringing (tinnitus) in the ears that may subside over time.

Medical criteria. Impulse noise greater than 140 peak decibels (dBP) is considered hazardous (references 1 and 2). Repeated, unprotected exposure to hazardous impulse noise will cause permanent hearing loss.

References.

(1) Military Standard (MIL-STD) 1474D, Department of Defense Design Criteria Standard, Noise Limits, 12 Feb 97.

(2) Department of the Army Pamphlet (DA PAM) 40-501, Hearing Conservation Program, 10 Dec 98.

APPENDIX C: ACOUSTIC ENERGY (BLAST OVERPRESSUE) IHHAR ELEMENT

Data requirements. Conduct blast overpressure testing on the materiel in accordance with the guidance for Blast Overpressure Analysis (reference 1). After the test is completed, send properly formatted data and a description of the test that contains the information in the Blast Overpressure Test Information Form (enclosure 1) to the US Army Public Health Command (Provisional) for analysis.

Health effects. When weapons fire they emit a blast wave that produces changes in airflow and density. Blast overpressure is important because exposures can produce injury if it is intense or occurs frequently. The risk of injury is related to the mechanics of the pressure wave and the physical properties of the tissue contacted. Air-containing organs such as the heart, lungs, esophagus, and stomach are relatively more susceptible to damage than denser tissues such as bone.

Medical criteria. Computer modeling is used for injury probability and severity classification and to predict the potential injury and pathology resulting from blast overpressures.

References.

(1) U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). 2005. Program Guidance for Blast Overpressure Analysis. http://chppm-www.apgea.army.mil/ergopgm/Docs/BOPProgGuidance,Revised1Dec05.pdf Now U.S. Army Public Health Command (Provisional) (USAPHC (Prov)).

Enclosure 1. BOP Test Information Form

BOP TEST INFORMATION FORM

_____
Weapon System Name

Tester's Name: _____

Phone: _____

Program Manager's (PM) Name: _____

PM's Email: _____

Test Date(s): _____

Test Center: _____

Has a Health Hazard Assessment been requested for this system? ☐ Yes ☐ No
HHA

Project Officer: _____

Purpose of the test:

_____

_____

_____

Indicate the type of BOP test conducted:

☐ Inside Vehicle. Describe:

_____

☐ Inside Enclosure. Describe:

_____

☐ Other Type. Describe:

_____

List any rounds that should be excluded due to errors or because they were "warmer" rounds:

List all conditions tested with relevant descriptive information:

[1] Position refers to the soldier's title on the weapon firing team such as gunner, ammo bearer, driver, and commander

[2] Posture refers to the position of the soldier's body when the weapon is fired such as standing, sitting, kneeling, and prone

[3] BTD Type refers to the type of BTD that represents the soldier for the test such as: 36 in, 30 in, 24 in, or Advanced BTD

[4] Variables are aspects of the test that are varied to yield difference in exposures such as weapon elevation, conditioning temperature of the round, or a special configuration for a vehicle or enclosure (hatch opened, hatch closed)

[5] Check "yes" to identify conditions that should not be tested due to error or other problem that may negatively impact the quality of the results; also note individual rounds should be excluded from the assessment in the appropriate area on page on

Condition #	Position[1]	Posture[2]	BTD Type[3]	Variables[4]	Exclude?[5]
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes
					☐ Yes

APPENDIX D: BIOLOGICAL SUBSTANCES (PATHOGENIC ORGANISMS – BLOODBORNE) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Guidance in Title 29, Code of Federal Regulations (CFR), Part 1910.1030 is applicable to situations where employers anticipate workers will be exposed to blood and other potentially infectious materials while carrying out their job duties (reference 1). Provide the key provisions including scope (who is covered), exposure control plans, methods of compliance, HBV vaccine, post-exposure evaluation and follow-up, bloodborne pathogen information and training, and record keeping to the U.S. Army Public Health Command (Provisional) to complete a health risk assessment.

(2) Ensure that the user identifies risk for occupational exposure(s) and the appropriate administrative controls (i.e., standard/universal precautions), engineering controls, safe work practices, and personal protective equipment needed to eliminate/control occupational exposures to bloodborne pathogens, and include these safeguards in appropriate technical manuals (TM) and training materials.

(3) Design any patient compartments, related medical equipment, and other hardware to facilitate decontamination and the temporary storage of regulated medical waste.

Health effects. Emergency responders (fire and police), ambulance operators, paramedics, healthcare workers, persons designated to render first aid, biomedical equipment personnel, mortuary affairs personnel, regulated medical waste handlers, housekeeping, and maintenance personnel have the potential for exposure to a variety of bloodborne pathogens (i.e. disease producing organisms). Potential exposures may result from patient care, cleaning/disinfection, maintenance, and improper disposal of contaminated medical equipment, supplies, blood or other potentially infectious materiel.

Medical criteria.

(1) Employers must ensure that personnel use standard/universal precautions whenever exposure to bloodborne pathogens is anticipated and follow federal laws, Army regulations, and acknowledged infection control guidelines when developing comprehensive Bloodborne Pathogen Programs. Comprehensive programs must identify risk and the key precautions that will be used to prevent occupational exposures to bloodborne pathogens, such as engineering and administrative controls, personal protective equipment, safe work practices, and proper handling and disposal of regulated medical waste (RMW).

(2) Generation of RMW is expected. Classify RMW, segregate it from general waste and stow it as appropriate for the materiel type (emergency response vehicle, evacuation aircraft, etc.). Provide proper packaging and adequate space to store of contaminated clothing, equipment, and RMW until it can be properly disposed (reference 1).

(3) Decontamination is defined as the use of Environmental Protection Agency (EPA) approved physical or chemical means to remove, inactivate or destroy bloodborne pathogens on a surface or item to the point they are no longer capable of transmitting infectious particles and the surface or item is rendered safe for handling, use or disposal.

References.

(1) Title 29, Code of Federal Regulations (CFR), Part 1910.1030, Bloodborne pathogens, U.S. Department of Labor (DOL), Occupational Safety and Health Administration (OSHA), www.osha.gov.

Supplemental References.

(1) Army Regulation (AR) 385-10, The Army Safety Program, 3 Sep 09.

(2) Department of the Army Pamphlet (DA PAM) 385-10, The Army Safety Program, 5 Aug 09.

(3) Army Regulation (AR) 40-5, Preventive Medicine, 25 May 07.

(4) Department of the Army Pamphlet (DA PAM) 40-11, Preventive Medicine, 19 Oct 09.

(5) U.S. Army Center for Health Promotion and Preventive Medicine Technical Guide (TG) 190, Guide to Managing Occupational Exposure to Bloodborne Pathogens, Apr 04.

(6) U.S. Army Center for Health Promotion and Preventive Medicine Technical Guide (TG) 195, Mortuary Affairs: Infectious Materials and CBRN Handling, 7 Jul 09.

(7) U.S. Army Medical Command (MEDCOM) Regulation 40- 35, Management of Regulated Medical Waste, Jul 08.

APPENDIX E: BIOLOGICAL SUBSTANCES (PATHOGENIC ORGANISMS – WATERBORNE) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Provide any water treatment, handing or storage information to include designs, specifications, materials, chemicals used, and processes to the U.S. Army Public Health Command (Provisional) to support a definitive HHA.

(2) Provide administrative, design and engineering controls used to prevent occupational exposures to waterborne pathogens. For example, clearly labeling all raw water equipment and systems as non-potable to avoid accidental cross-contamination or interchange and control the spread of biological pathogens, or use of personal protective equipment.

(3) Provide intended use of each water source and test results of system performance to include analysis of product water for microbial pathogens, disinfectant residual, as well as nuclear, biological and chemical contaminants outlined in tri-service standards as defined in Technical Bulletin Medical (TB MED) 577 (reference 1).

(4) Ensure water generation systems are capable of producing acceptable water quality within the span of operational scenarios. Assess function of materiel during extreme conditions such as temperature, shock, vibration and dustiness.

Health effects. Raw water sources and wastewater can contain microbial pathogens such as bacteria, protozoans, and viruses from excreta, or toxic organic or inorganic substances from pollution sources that can pose potentials threat to human health. Exposure to pathogenic organisms can occur by inhalation, ingestion, or absorption. Effects of contact with a pathogenic or toxic agent can result in a number of illnesses such as gastroenteritis, skin or eye infections, hepatitis, occupational asthma or leptospirosis (reference 2).

Medical criteria.

(1) Basic personal protective equipment (PPE) such as hip waders, rubber gloves, rubber apron or other waterproof clothing, and eye protection will provide protection to the operators from pathogenic organisms.

(2) Routine personal hygiene, such as frequent hand washing, showering, avoiding the use of tobacco, food and drinking while operating water production materiel will help minimize the potential exposure to pathogens (reference 3).

(3) If intended use of water supply is for personal hygiene, heating the water to 95-105 degrees Fahrenheit (F) will promote personal hygiene and aid in the prevention of the spread of biological pathogens.

(4) Water equipment should be cleaned routinely to remove any mold, mildew or bacterial growth. Tanks, hoses and other equipment should be disinfected before use (reference 1).

References.

(1) Technical Bulletin Medical (TB MED) 577, Sanitary Control and Surveillance of Field Water Supplies, 15 Dec 05.

(2) Field Manual (FM) 21-10, Field Hygiene and Sanitation, 21 Jun 00.

(3) Field Manual (FM) 4-02.33, Control of Communicable Diseases, 18th Edition, 01 Jun 05.

Supplemental References.

(1) Technical Bulletin (TB) 43-0153, Water Supply Afloat, 01 Sep 02.

(2) Army Regulation (AR) 40-5, Preventive Medicine, 25 May 07.

APPENDIX F: BIOLOGICAL SUBSTANCES (SANITATION) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Provide the U.S. Army Public Health Command (Provisional) with the detailed drinking water, waste holding system design, foodservice, anticipated type of rations served, laundry, shower and toilet facility information to include construction, cleaning, storage and maintenance details to support the preparation of a definitive HHAR on this materiel.

(2) Potable water.

(a) Provide manufacturer specifications of water distribution systems and storage tanks. Equipment must be National Sanitation Foundation (NSF) certified and conform to the Uniform Plumbing Code (UPC).

(b) Show documentation demonstrating the potable water storage tanks and outlets are of adequate numbers and sized to support user populations during all operational scenarios.

(c) Outline disinfection procedures for the potable water and distribution system prior to and during use. These procedures shall be in accordance with Technical Bulletin Medical (TB MED) 576 and/or TB MED 577 (references 1 and 2).

(d) Provide documentation of a comprehensive cross-connection control survey on the potable water system, in accordance with Environmental Protection Agency (EPA) guidance (reference 3) and American Water Works Association Guidelines (reference 4).

(e) Supply manufacturer operation and maintenance specifications of reverse osmosis elements and/or bromination system where applicable. Provide justification for use of bromine disinfectant and OTSG approval if necessary.

(3) Waste disposal.

(a) Provide documentation demonstrating that the wastewater disposal system is sized to support user populations during operational scenarios as well as associated health and safety operating procedures (references 5 and 6).

(b) Provide a description and specifications of any waste incinerator to include operating procedures.

(c) Provide documentation of the required user and 1st echelon maintenance of waste disposal systems including sewage and other waste systems.

(4) Foodservice sanitation.

(a) Provide verification, final design, construction, cleaning, and maintenance specifications of foodservice equipment, facilities or materiel to determine compliance with the requirements in TB MED 530 (reference 7). Non-field foodservice equipment must be also be NSF listed. Field foodservice equipment must meet the general requirements for food equipment.

(b) Provide a description of the menu, additional non-food service equipment, hand washing and ventilation systems used in food service operations.

(5) Condensate. Provide details on any condensate drainage systems and procedures to prevent accumulation of stagnant water.

(6) Toilet facilities. If equipped, provide detailed system design, construction, cleaning and maintenance information to support a definitive HHAR. Facilities should be sized so capacity meets requirements of total number by sex of crew and passengers for required mission duration. General information on toilet facilities can be found in Title 29, Code of Federal Regulations (CFR) 1910.141 (reference 8).

(7) Shower facilities. If equipped, provide detailed system design, construction, cleaning and maintenance information to support a definitive HHAR. Facilities should be sized to meet the maximum anticipated bather load.

(8) Laundry. If equipped, provide verification of countermeasures to prevent human exposure to laundry and cross-contamination of clean laundry (reference 9).

(9) Pest Control. Provide validation that all occupied structures and waste collection areas include screens, air curtains (food service), or other pest exclusion devices (reference 10).

Health effects. Ingestion, inhalation, or absorption of pathogenic microorganisms, their toxins, and enzymes can cause a variety of illnesses. Contaminated water or exposure to excreta can result in conditions such as Hepatitis A, dysentery, cholera, or other diarrheal diseases. The presence of chemicals in water supplies can lead to acute or delayed toxicity. Insect vectors can transmit malaria, encephalitis or leishmaniasis causing significant temporary or permanent conditions. Poor solid waste disposal can magnify the potential for exposure to disease causing organisms.

Medical criteria.

(1) Potable water. An adequate supply of potable water is essential to health and well-being. Army materiel will use the policies and procedures in preventive medicine guidance to provide and maintain a safe potable water supply (references 2 and 11). Substandard facilities for water distribution or storage may adversely affect the quality of the water being supplied even though it leaves the treatment facility at satisfactory chemical and microbiological quality.

(2) Waste disposal. The Army policy is to dispose of all classes of waste (water, solid, and hazardous) in a manner that protects the environment and preserves human health (reference 11).

(3) Foodservice facilities. Foodservice facilities must meet certification requirements of the NSF International, Underwriter's Laboratory, Inc., or other laboratory or national consensus standards acceptable to the Surgeon General (reference 7). Layout of kitchen equipment must consider workflow and be designed to minimize the potential for contaminated items to contact clean surfaces, equipment, utensils and food to help prevent the spread of food-borne disease.

(4) Condensate. The water vapor that condenses from cooling coils is a potential medium for microorganisms. These microorganisms can become aerosolized and entrained in the air supply and cause a range of illnesses.

(5) Toilet facilities. Facilities must have convenient provisions for hand washing devices or sanitizing body contact surfaces on the toilet. These provisions help to prevent/control the spread of disease.

(6) Soldiers and maintainers of Army equipment must be protected against exposure to infectious diseases. Provisions must be made for personal protective equipment as well as other procedures to protect the workers and crew from biological agents.

References.

(1) Technical Bulletin Medical (TB MED) 576, Sanitary Control and Surveillance of Water Supplies at Fixed Installations, 15 Mar 82.

(2) Technical Bulletin Medical (TB MED) 577, Sanitary Control and Surveillance of Field Water Supplies, Dec 05.

(3) Environmental Protection Agency (EPA) Cross-Connection Control Manual, EPA 816-R-03-002, Feb 03.

(4) American Water Works Association (AWWA), Recommended Practice for Backflow Prevention and Cross-Connection Control (M14), 04.

(5) Title 40, Code of Federal Regulations (CFR), Part 243.200-1, Guidelines for the Storage and Collection of Residential, Commercial and Institutional Solid Waste.

(6) American National Standards Institute (ANSI) Standard A119.2, Recreational Vehicles, 02.

(7) Technical Bulletin Medical (TB MED 530), Occupational and Environmental Health Food Sanitation, 30 Oct 02.

(8) Title 29, Code of Federal Regulations (CFR), Part 1910.141, Sanitation, 01 Jul 03.

(9) Field Manual (FM) 10-280, Mobile Field Laundry, Clothing Exchange and Bath Options, 02 Dec 83.

(10) Technical Bulletin Medical (TB MED 561), Pest Surveillance, 01 Jun 92.

(11) Army Regulation (AR) 40-5, Preventive Medicine, 25 May 07.

Supplemental References.

(1) Technical Bulletin (TB) 43-0153, Water Supply Afloat, 30 Aug 03.

(2) Field Manual (FM) 10-52, Water Supply in Theatres of Operation, 11 Jul 90.

(3) Field Manual (FM) 10-52-1, Water Supply Point Equipment and Operations, 18 Jun 91.

(4) Field Manual (FM) 21-10, Field Hygiene and Sanitation, 21 Jun 00.

APPENDIX G: CHEMICAL SUBSTANCES IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Provide detailed information on the chemical composition of any propellants to the U.S. Army Public Health Command (Provisional) for a definitive HHA on weapon combustion products. Sampling for weapon combustion hazards should follow test guidelines in International Test Operating Procedure (TOP) 2-2-614 (reference 1).

(2) Provide detailed design information and engine exhaust product test data, collected according to TOP 2-2-614 (reference 1) for completion of the HHA on engine exhaust products. Design materiel so that engine exhaust and other chemical products are prevented from directly entering breathing zone of operators and maintainers and not located in close proximity to air intakes.

(3) Provide the material safety data sheet (MSDS), composition, purpose and quantity of any miscellaneous chemicals used in the operation and maintenance of the materiel to the U.S. Army Public Health Command (Provisional). Make MSDSs available to users and maintainers, including information on specific use, handling, storage and disposal requirements in appropriate technical manuals (TM).

(4) Eliminate or reduce the number of miscellaneous toxic/hazardous chemicals used by design or substitution to the maximum extent feasible.

Health effects.

(1) Weapon combustion products and engine exhaust from vehicle engines, generators or other sources are a primary source of potential toxic gas exposures. Engine exhaust products are a complex mixture of a variety of hazardous chemical substances. Other potential sources of exposures to chemical substances include fuels, oils, lubricants, cleaners/solvents, fire extinguishing agents, battery acid/chemicals, refrigerant and other miscellaneous chemicals used in the life cycle management of materiel. Soldiers can suffer a variety of health effects based upon the physical form of the chemical, the route of entry, and duration of exposure.

(2) Depending on the duration and level of exposure, Soldiers can suffer a variety of health effects resulting in a range of outcomes from performance decrement to death. Irritants or corrosive chemicals can cause inflammation, burns or blisters, fibrogenic materials lead to a loss of lung function, allergic reactions can lead to asthma-type diseases, or dermatitis. Carcinogenic materials can cause cancers in affected organs or tissues, possibly leading to death. Poisonous chemicals can lead to cell death, and asphyxiants will affect the body’s ability to utilize oxygen.

Medical criteria. Health-based exposure limits for chemical substances adhere to guidelines published by the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV), or military unique criteria outlined in Military Standard (MIL-STD)-1472F. These limits formulate a level of exposure that the typical worker can experience during a lifetime without adverse health effects. The risk determination process considers levels of exposure for traditional 8-hour workday, acute exposures under 15 minutes in duration, and a ceiling limit that should not be exceeded during any part of the workday exposure.

References.

(1) Test Operating Procedures (TOP) 2-2-614, Toxic Hazards Test for Vehicle and Other Equipment, 31 Oct 03.

APPENDIX H: OXYGEN DEFICIENCY IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Provide ventilation test data (e.g. maximum personnel, area volume, total fresh and recirculated airflow rates) collected in accordance with Test Operating Procedure (TOP) 1-2-610 (reference 2) to this Center for completion of a comprehensive HHA.

(2) Ensure the design and operation of vehicle cabs, shelter ventilation systems or environmental control units provide the required rate of fresh and recirculated air to occupants during all operational scenarios in accordance with Military Standard (MIL-STD)-1472F paragraphs 5.8.1.2 and 5.12.6.2 (reference 1).

(3) Ensure the design of maintenance-type shelters includes general ventilation and local exhaust ventilation (LEV) as described in MIL-STD-1472F (reference 1) to capture and eliminate airborne health hazards generated during maintenance activities.

(4) Refer to the Occupational Safety and Health Administration's (OSHA) definitions of "confined space" or "permit-required confined space" for additional guidance on ventilation requirements (reference 3). A confined space has limited means for entry or exit, and is not designated for continuous occupancy. A permit-required confined space has one or more of the following characteristics: contains or has the potential to contain a hazardous atmosphere, contains a material that has the potential to engulf an entrant, has walls that converge inward or floors that slope downward and taper into a smaller area which could trap or asphyxiate an entrant, or contains any other recognized safety or health hazard (e.g. unguarded machinery, exposed live wires or heat stress).

Health effects. General ventilation of occupied spaces provides fresh and recirculated air for adequate breathing air and the elimination of toxic chemicals. It also contributes to the comfort and efficiency of personnel and improved worker health since adequate ventilation helps to control odors, extreme temperature and humidity conditions, carbon dioxide buildup, and the spread of communicable diseases via contamination of airborne dust and droplets.

Medical criteria.

(1) The MIL-STD-1472F paragraph 5.13.7.4 (reference 1) recommends personnel not be exposed to the concentrations of toxic substances in excess of the limits specified in either the Department of Defense Occupational Safety and Health standards or specialized standards applicable to military unique equipment, systems, or operations. The possibility of exposure at levels greater than acceptable could exist if the materiel does not meet testing requirements.

(2) The most restrictive fresh air requirement for mobile enclosures, shelters, or buttoned up vehicle cabs contained in MIL-STD-1472F, Figure 35, is approximately 20 cubic feet per minute per person (cfm/person) (reference 1). As the enclosure or shelter volume per occupant increases, the outdoor/fresh air requirement decreases. Figure 35 also contains the outdoor/fresh and recirculated air required for variations in shelter volume/number of occupants. Outside fresh air should be provided at a minimum rate of 20 cfm/person for traditional vehicle cabs. The air velocity at each vehicle occupant's head location should be adjustable either continuously or with not less than three settings (i.e. off, low, high) from near zero to at least 400 feet per minute (reference 1).

References.

(1) Military Standard (MIL-STD) 1472F, Department of Defense Design Criteria Standard - Human Engineering, 23 Aug 99.

(2) Test Operations Procedure (TOP) 1-2-610, Human Factors Engineering Part I Test Procedures, 15 May 90.

(3) Safety and Health Topics: Confined Spaces, 10 Jan 08, Occupational Safety and Health Administration (http://www.osha.gov/SLTC/confinedspaces/index.html).

Supplemental References.

(1) Military Handbook (MIL-HDBK) 759C, Department of Defense Handbook for Human Engineering Design Guidelines, 31 Jul 95.

APPENDIX I: RADIATION ENERGY (OPTICAL RADIATION) IHHAR ELEMENT

Data Requirements and initial recommendations.

(1) Contact the U.S. Army Public Health Command (Provisional) (USAPHC (Prov)) Laser/Optical Radiation Program to request a laser-optical radiation survey on new laser-optical radiation sources being developed for the equipment during RDT&E and prior to purchase and use by the Army in accordance with Department of the Army Pamphlet (DA PAM) 40-11 (reference 1). An initial paper analysis should be completed and followed up with a survey of the hardware, when available.

(2) Provide a complete list of laser-optical radiation sources used in/on each piece of equipment to USAPHC (Prov) to support a definitive HHAR on each item. For each laser-optical radiation source, provide a technical POC, mode of operation (continuous wave, single pulse, or multiple pulse), primary use, transmitter wavelength, maximum output power, maximum energy per pulse, pulse width at ½ power points, maximum pulse repetition frequency, distance from aperture to waist, total pointing error (TPE) in µrad, exit beam diameter at 1/e points, beam divergence at 1/e points, beam distribution, beam profile, and laser medium. Also provide details on day-view optics (i.e., magnifying power, laser protection, and boresighting procedures) and safety features (e.g., interlocks).

Health effects. Most materiel will likely use one of the following laser-optical radiation sources; laser rangefinder/designator/illuminator/pointer, nonlethal weapon, and/or high intensity lights. For most sources, the effects of exposure are determined by the wavelength and dose received by the Soldier and is usually limited to the skin and eye. The eye is the most sensitive, with exposed skin being vulnerable to only higher-powered lasers.

Medical Criteria. Laser radiation should not be confused with ionizing radiation, such as X-rays and gamma rays. Laser hazards exist only along the beam path, unlike radioactive materials that emit radiation in all directions. For lasers that are focused by the eye (400-1,400 nanometers (nm)), very little energy is required to cause injury. This is due to concentration of the laser light by a factor of approximately 100,000 times. This is similar to burning a piece of paper by focusing the sunlight with a magnifying glass. In addition to the focusing by the eye, laser wavelengths greater than 700 nm are invisible. Since a person cannot see these wavelengths, he or she may be exposed to the beam longer than what would be expected for a visible wavelength laser beam, which would be uncomfortably bright to view. For this reason, a 10-second (s) exposure is accepted as the longest duration that anyone could fixate on the same point in space and, therefore, receive the laser energy to the same part of the eye. Classification, hazard distance, and optical density calculations for lasers whose wavelength is greater than 700 nm are based on a 10-s exposure.

References.

(1) Department of the Army Pamphlet (DA PAM) 40-11, Preventive Medicine, (RAR) 19 Oct 09.

Supplemental References.

(1) Department of Defense Instruction (DODI) 6055.15, DoD Laser Protection Program, 4 May 07.

(2) Army Regulation (AR) 385-10, The Army Safety Program, (RAR) 03 Sep 09.

(3) DA PAM 385-24, The Army Radiation Safety Program, 24 Aug 07.

(4) Military Standard (MIL-STD) 1425A, DoD Design Criteria Standard, Safety Design Requirements for Military Lasers and Associated Support Equipment, 30 Aug 91.

(5) American National Standards (ANSI), “Safe Use of Lasers,” American National Standard Z136.1 - 2007, Orlando, FL, Laser Institute of America.

(6) International Electrotechnical Commission (IEC), “Safety of Laser Products – Part 1: Equipment classification, requirements, and user’s guide,” IEC 60825-1 Ed. 2, 2007-03, Geneva, Switzerland, IEC.

(7) Technical Bulletin Medical (TB MED) 524, Control of Hazards to Health From Laser Radiation, 31 Jan 06.

APPENDIX J: RADIATION ENERGY (RADIOFREQUENCY RADIATION) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Contact the U.S. Army Public Health Command (Provisional) (USAPHC (Prov)) Radio Frequency/Ultrasound Program to request a radiofrequency radiation (RFR) survey of new RFR sources being developed during research, development, test and evaluation (RDT&E) and prior to purchase and use by the Army in accordance with Department of the Army Pamphlet (DA PAM) 40-11 (reference 1). In lieu of an RFR survey by USAPHC (Prov), provide data that supports an RFR assessment of these sources or provide an equivalent RFR survey from another Department of Defense Center.

(2) Provide a complete list of RFR sources used in/on each equipment variant to USAPHC (Prov) to support a definitive Health Hazard Assessment (HHA). For non-government furnished equipment that emits RFR, provide a technical point of contact, frequency, peak and average power output, pulse repetition frequency, pulse width, duty cycle, antenna type, size, and gain, transmission line length and losses, and the source's location on the equipment. See Department of Defense Form (DD Form) 1494 for additional information and guidance (reference 2).

Health effects. The primary effect of absorbed RFR energy is *in-vivo* temperature increase. Secondary effects (i.e., those arising from temperature increases) may include tissue damage with the lens of the eye being the most sensitive part of the body. Electromagnetic energy can also induce electrical currents, stimulating nerves or muscles. In some RF environments, contact with excessively high RF voltages may result in an RF shock or burn.

Medical criteria.

(1) The Department of Defense and Army standards (references 3 – 6) for permissible exposure to electromagnetic fields (EMFs) and radio frequency radiation (RFR) in the 0 to 300 gigahertz (GHz) frequency spectrum is based on those of the American National Standards Institute/Institute of Electrical and Electronics Engineers C95.1 and C95.6 standards (references 7 and 8). These standards are based on established adverse health effects and specify permissible exposure limits (PEL) or maximum permissible exposures (MPE) for the protection of personnel. There are no expectations that any adverse health effects will occur with exposures that are within the MPEs, even under repeated or long-term exposure conditions. A minimum safety factor of ten is incorporated into these standards. These MPEs are also assessed with reference to an averaging time that varies with frequency.

(2) The MPEs are given in terms of root mean square (rms) electric field strengths in volts per meter (V/m), rms magnetic field strengths in amperes per meter (A/m), plane-wave equivalent power densities in either milliwatts per square centimeter (mW/cm^2) or

watts per square meter (W/m^2), or the induced and contact currents in amperes (A). The MPEs at frequencies below 5 MHz are established to limit adverse health effects due to electrostimulation. The MPEs in the frequencies between 100 kHz and 3 GHz were derived to limit the specific absorption rates (SARs) to no greater than 0.4 watts per kilogram (W/kg) for whole-body exposure or 10 W/kg averaged over any 10g of tissue, for localized exposure. The MPEs in the frequencies between 3 GHz and 300 GHz are established to limit adverse health effects due to incident power density. An open voltage of 140 V (rms) in RF fields is a conservative criterion used to define a potential RF shock or burn hazard situation.

References.

(1) Department of the Army Pamphlet (DA PAM) 40-11, Preventive Medicine, (RAR 002 19 Oct 09), 22 Jul 05.

(2) Department of Defense (DD) Form 1494, Application for Equipment Frequency Allocation, Aug 96.

(3) Army Regulation (AR) 385-10, The Army Safety Program, (RAR 001 03 Sep 09), 23 Aug 07.

(4) Army Regulation (AR) 40-5, Preventive Medicine, 25 May 07.

(5) Department of Defense Instruction (DoDI) 6055.11, Protection of DoD Personnel from Electromagnetic Fields, 19 Aug 09.

(6) Department of the Army Pamphlet (DA PAM) 385–24, The Army Radiation Safety Program, 24 Aug 07.

(7) American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE) C95.1-2005, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300GHz, 19 Apr 06.

(8) American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE) C95.6 IEEE Standard for Safety Level with Respect to Human Exposure to Radiofrequency Electromagnetic Fields, 0-3 kHz, 23 Oct 02.

Supplemental References

(1) Technical Bulletin Medical (TB MED) 523, Control of Hazards to Health From Microwave and Radio Frequency Radiation and Ultrasound, Jul 80.

(2) Military Standard (MIL STD) 464, Electromagnetic Environmental Effects, Requirements for Systems, 18 Mar 97.

(3) Title 10, Code of Federal Regulations (CFR), Energy, 1 January 2010.

APPENDIX K: RADIATION ENERGY (IONIZING RADIATION) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Request an evaluation of improved, new, or commercial equipment/systems containing ionizing radiation sources prior to purchase and use by the Army (reference 2). The POC for ionizing radiation surveys is the Health Physics Program.

(2) Provide a detailed list of ionizing radiation sources, with the information described below to this Center to support a definitive HHA.

(a) For radioactive material: the isotope(s), chemical or physical form, amount of isotope in each system and whether the source is sealed, unsealed, plated or foil.

(b) For ionizing devices

i. For x-ray devices: operating parameters, radiation output, and system certification.

ii. For a neutron source: operating parameters, neutron emission rate, and average energy emitted.

(c) Verification that x-ray devices meet applicable Title 10, Code of Federal Regulations (10 CFR) or 21 CFR requirements.

(d) Verification that radioactive material sources meet appropriate American National Standards Institute requirements.

(e) Verification that Nuclear Regulatory Commission license or Department of the Army authorizes the radioactive material or x-ray device.

(f) Development of special operational procedures for production and deployment.

(g) Storage, use, maintenance, disposal and special handling requirements.

(3) Eliminate/control exposures to ionizing radiation sources to the crew, passengers, and maintainers to the maximum extent feasible during design, manufacture and installation of commercial or government equipment containing ionizing radiation sources (reference 1).

Health Effects. The absorption of ionizing radiation in biological material or systems may result in biological effects. The nature of these effects depends on the amount of radiation absorbed and on the molecules that are affected. For low doses of ionizing radiation, the primary effect of interest is an increased risk of cancer in the future.

Genetic effects (effects that appear in future generations) are possible but unlikely at low doses and at low dose rates. Title 10, CFR, Department of the Army Pamphlet (DA PAM) 385-24, and Army Regulation (AR) 385-10 provide the ionizing radiation safety criteria for personnel potentially exposed to ionizing radiation (references 3, 4, and 5) .

Medical Criteria. Regulatory dose limits have been established for occupationally exposed individuals to prevent or minimize potential health risks. The primary limit is an effective dose not exceeding 50 millisievert (mSv) (5000 millirem (mrem)) per year. Any occupationally exposed individual who is likely to receive a dose (from external sources) in excess of 5 mSv (500 mrem) per year must be issued a dosimeter to monitor his/her individual radiation dose.

References.

(1) Memorandum, Office of the Chief of Staff, DACS-SF, subject: Eliminate Hazards Through Design Selection, 10 Jun 04.

(2) Army Regulation (AR) 40-5, Preventive Medicine, 25 May 07.

(3) Title 10, Code of Federal Regulations (CFR), Energy, 1 Jan 10.

(4) Department of the Army Pamphlet (DA PAM) 385-24, Army Radiation Safety Program, (RAR) 26 Mar 09.

(5) Army Regulation (AR) 385-10, The Army Safety Program, (RAR) 03 Sep 09.

Supplemental References.

(1) American National Standards Institute (ANSI) N43.3-2008, Installations Using Non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up to 10 MeV, American National Standards Institute, 1 Jan 08.

(2) American National Standards Institute (ANSI) N43.17-2002, Radiation Safety for Personnel Security Screening Systems Using X-rays, American National Standards Institute, 3 Apr 02.

(3) Department of the Army Pamphlet (DA PAM) 40-18, Personnel Dosimetry Guidance and Dose Recording Procedures for Personnel Occupationally Exposed to Ionizing Radiation, 30 Jun 95.

(4) Title 21, Code of Federal Regulations (CFR), Chapter I, Subchapter J, Radiological Health, 1 Apr 09.

(5) Department of Defense Instruction (DoDI) 6055.8, Occupational Radiation Protection Program, 6 May 96.

(6) American National Standards Institute/Health Physics Society (ANSI/HPS) N13.41-1997, Criteria for Performing Multiple Dosimetry, American National Standards Institute, 1997.

(7) International Commission on Radiological Protection (ICRP) Publication Number 26, International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection, 1977.

(8) International Commission on Radiological Protection (ICRP) Publication Number 60, International Commission on Radiological Protection, 1990 Recommendations of the International Commission on Radiological Protection, 1991.

(10) Shleien, B. [ed.], The Health Physics and Radiological Health Handbook, Revised Edition, 31 Dec 92.

(11) United States Environmental Protection Agency (EPA), Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Sep 88.

(12) Cember, H., Introduction to Health Physics, Third Edition, 1996.

(13) National Council of Radiation Protection and Measurements, Commentary No. 16, Screening of Humans for Security Purposes Using Ionizing Radiation Scanning Systems, 2003.

(14) Army Regulation (AR) 40-10, Health Hazard Assessment Program in Support of the Army Acquisition Process, 27 Jul 07.

(15) DA PAM 40-11, Preventive Medicine, (RAR) 19 Oct 09.

(16) Technical Manual (TM) 1-1500-335-23 (also known as TO 33B-1-1), Non-Destructive Inspection Methods, Basic Theory, 15 Jun 07.

APPENDIX L: TEMPERATURE EXTREMES IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Test heating and cooling performance in accordance with Test Operations Procedure (TOP) 2-2-816 and/or TOP 1-2-610 (references 1 and 2), simulate all heat gains, and provide Wet Bulb Globe Temperature data at occupant head, chest and foot positions to support a definitive health hazard assessment. Test data should demonstrate that the materiel's heating and cooling system can maintain the required temperature so that a comprehensive assessment of heat and cold stress can be performed.

(2) Design heating and cooling performance to meet or exceed the performance/design criteria requirements contained in Military Standard (MIL-STD) 1472F (reference 3).

Health effects. Soldier exposures to excessive levels and duration of either heat or cold stress may cause vigilance and performance decrements, temporary or permanent injury, and death.

Medical criteria.

(1) Army system specifications routinely require operation in basic and hot climactic design types (-25 degrees Fahrenheit (^{o}F) to120 ^{o}F) as defined in Army Regulation (AR) 70-38 (Reference 4) and is intended to operate anywhere Joint Forces deploy.

(2) Guidance addressing ambient temperatures, temperature uniformity, humidity, micro-climate cooling and correction factors for the wear of protective clothing are provided in MIL-STD-1472F, paragraphs 5.8.1 and 5.12.6 for personnel enclosures/shelters and vehicle cabs, respectively (reference 3).

(3) Mobile personnel enclosures or shelters used for detailed work or occupied for extended periods must have a cooling system designed to maintain the effective temperature or corrected effective temperature not greater than 85 ^{o}F. The system will be designed so that cold air discharge is not directed on Soldiers. The hot climate comfort zone for inhabited spaces is defined as 66 ^{o}F to 75 ^{o}F.

(4) The heating system should be designed to maintain the interior dry bulb temperature above 50 ^{o}F. The heating system will also be designed so that hot air discharge is not directed on Soldiers. The cold climate comfort zone for inhabited compartments/shelters is defined as 65 ^{o}F to 70 ^{o}F (reference 3).

(5) Traditional vehicle cabs are to be equipped with an air conditioning system capable of meeting the performance requirements in MIL-STD-1472F, paragraph 5.8.1, whenever the vehicle's mission profile requires Soldiers to occupy the cab for period of greater than 30 minutes with a temperature greater than 75 ^{o}F. Traditional vehicle cabs must have a heating system capable of maintaining temperatures above 68 ^{o}F during occupancy when

Soldiers do not wear Arctic clothing and exposure exceeds three hours. When Soldiers wear Arctic clothing, cab heaters are to maintain a temperature of not less than 41 ^{o}F at the minimum ambient design operating temperature of the vehicle when moving at two-thirds maximum speed and the defrosters operating at maximum capacity. The heater is to achieve performance requirements with in one hour of operation (reference 3).

References.

(1) Test Operations Procedure (TOP) 2-2-816, Tracked Vehicle Temperature Tests, 1987.

(2) Test Operations Procedure (TOP) 1-2-610, Human Factors Engineering Part I – Test Procedures, 15 May 90.

(3) Military Standard (MIL-STD) 1472F, Department of Defense Design Criteria Standard – Human Engineering, 23 Aug 99.

(4) Army Regulation (AR) 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 15 Sep 79.

Supplemental References

(1) Military Handbook (MIL-HDBK) 759C, Department of Defense Handbook for Human Engineering Guidelines, 31 Jul 95.

APPENDIX M: MUSCULOSKELETAL TRAUMA (LIFT AND CARRY) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Determine the weights and lift requirements (e.g. mechanical or multi-Soldier lift) and include warning labels with those weight and lift/carry requirements to the applicable components and in the technical manuals (TM).

(2) Provide data for analysis as identified on the Health Hazard Assessment Lifting Analysis Worksheet (Enclosure 1) to support the completion of a definitive HHA on this potential health hazard concern.

(3) Apply the design guidance for efficient handling contained in Military Standard (MIL-STD) 1472F paragraph 5.9.11 (reference 1) to the materiel design to the maximum extent feasible. Place emphasis on heavy items that require manual lift/adjustment.

Health effects. A potential source of exposure to musculoskeletal trauma is the lift/carry of heavy components or equipment. Some components may require multiple personnel to lift, carry, and/or install. Manual handling and lifting are a major cause of work-related lower back pain (LBP) and impairment and shoulder or arm pain. The LBP can occur by direct trauma, a single exertion (overexertion), or as a result of multiple exertions (repetitive trauma). The LBP and impairment are also associated with other work-related factors such as pushing and pulling activities, extreme postures such as forward flexion, and cyclic loading.

Medical criteria.

(1) The MIL-STD-1472F paragraph 5.9.11 (reference 1) contains design guidance for efficient handling. Lifting limits or the maximum values in determining the design weight of items required for one or multiple-Soldier lifting is included. There is also information presented regarding lifter interference with one another, lift frequency, lift height, lift load size, carrying limits, object carry size, mixed gender lift and carry, labels, handles and grasp areas, and push and pull forces. Each of these should be considered when requiring Soldiers to perform lift, carry, and push and pull tasks during use of the materiel and it’s components.

(2) Each item required to be manually lifted/carried should be labeled with their weight and lifting requirements according to MIL-STD-1472F, paragraph 5.9.11.3.9. Where mechanical or power lift is required, hoist and lift points shall be provided and clearly labeled. All lift and carry information should be included in the TMs.

References.

(1) Military Standard (MIL-STD) 1472F, Department of Defense Design Criteria Standard – Human Engineering, 23 Aug 99.

ENCLOSURE 1

Health Hazard Assessment Lifting Analysis Worksheet

Name of System:

_____

Name of System Component or Object:

_____

General Information

Manpower	
- Number	What is the maximum number of personnel available for assignment to lifting teams? _____
- Gender	☐ Male only ☐ Female only ☐ Mixed gender team

Load Transfers (lifting and/or lowering of an item from one location to another)
Complete the following information for each item weighing 35 pounds or more

Object Characteristics	
- Dimensions (in)	Length _____ Width _____ Height _____
- Weight (lb)	Enter object weight: _____
- Weight Distribution	☐ Even ☐ Uneven
- Hand Holds	While transferring the load how many hands does each lifter use to grasp the object? ☐ One hand ☐ Two hands
	Description of hand holds (respond to only one of two options): ☐ Object does not have handles and is directly grasped Grasp location is: ☐ slippery ☐ not slippery ☐ Handles are integrated into the object's design Object hosts _____ handles (enter number) Handles can accommodate gloved hands? ☐ Y ☐ N
Load Transfer Activity	
- Posture(s) used	☐ Standing/stooping ☐ Kneeling ☐ Lying
- Vertical travel distance	Check most appropriate description ☐ Between Floor to Handler's Knuckle Height ☐ Between Knuckle and Shoulder Heights ☐ Between Floor and Shoulder Height
	Transfer includes lifting above shoulder height? ☐ Y ☐ N
	Does the load need to be maneuvered around an obstacle or through a space with limited clearance? ☐ Y ☐ N
- Repetitiveness	Will this object be moved > 3 times during a mission? ☐ Y ☐ N If yes: Enter estimated # of times it will be moved: _____ Enter the transfer rate (i.e., lifts per minute): _____ Enter the duration of the transfer task (min): _____

- Footing	Individuals will stand on a slippery, unstable or moving surface

	while lifting/lowering objects: ☐ Y ☐ N
- Carrying	Moving this object requires: ☐ Carrying; distance _____ ft ☐ Negotiating a ramp; run length _____ in; rise (height) _____ in ☐ Negotiating stairs; run length _____ in; rise (height) _____ in ☐ Negotiating a ladder; length _____ in; incline angle _____ deg
Handling Equipment	
	Will this item be moved manually (no lifting device)? ☐ Y ☐ N

APPENDIX N: MUSCULOSKELETAL TRAUMA (WHOLE BODY VIBRATION) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Collect WBV test data in accordance with the guidance cited in International Standards Organization documents (references 1 and 2). Provide WBV test data for the materiel to the U.S. Army Public Health Command (Provisional) reported in the British Columbia Research format so that a definitive health hazard assessment can be completed (Enclosure 1).

(2) Eliminate or control exposures to whole body vibration (WBV) by design to the maximum extent feasible.

Health effects. Personnel operating and riding materiel may be subjected to excessive WBV during prolonged use or movement even at low speeds over improved terrain. The health effects associated with exposure to WBV include herniated and degenerative lumbar disc disease and low back pain. A number of engineering controls/design features are available to reduce or control Soldier exposures to WBV (e.g. seat padding/suspension, vehicle suspension) and should be applied to the maximum extent feasible to the design.

Medical criteria. To minimize the effects of whole body vibration from vehicles on health, the root-mean square value of the frequency-weighted translational accelerations should not exceed the health guidance cautions defined by ISO 2631-1 Annex B (reference 1). If possible, exposure within the health guidance caution zone should be avoided. Frequencies below 20 Hz, where major body resonances occur, should be avoided. To preclude impairment of visual tasks, vibration between 20 Hz and 70 Hz should be minimized. The transmission of higher frequency vibration through any seating systems should also be minimized, especially where the body or head come in contact with the seatback or headrest.

References.

(1) International Standards Organization (ISO) 2631-1, Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-body Vibration Part 1: General Requirements, 1997.

(2) International Standards Organization (ISO) 2631-5, Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-body Vibration Part 5: Method for Evaluation of Vibration Containing Multiple Shocks, 2004.

Supplemental References.

(1) Military Standard (MIL-STD) 1472F, Department of Defense Design Criteria Standard, Human Engineering, 23 Aug 99.

ENCLOSURE 1

WHOLE-BODY VIBRATION DATA COLLECTION FORMAT
(BRITISH COLUMBIA RESEARCH DATA FILE STRUCTURE)

Acceleration data should be collected over a range of speeds and terrains that the vehicle is likely to encounter. Refer to MIL-STD-1472F, ISO 2631-1:1997 and ISO 2631-5:2004 for complete instructions on proper whole-body vibration data collection.

Acceleration data obtained from ride pads should be stored in text files according to a special data structure described below. This data file structure was initially developed and used by British Columbia Research (BCR) Institute as part of its contract with the U.S. Army Aeromedical Research Laboratory to develop a new assessment method of repeated shock in Army tactical vehicles. Data must be collected at a sample rate greater than 160 hertz (Hz). Data must be recorded in accordance with ISO 2631-1:1997.

The filenames must have the "BCR" extension, which is the only extension recognized by WBV-JOLT software (version 5.0 and earlier).

Each BCR file starts with a header that includes three descriptive groups of information about the test parameters (channel labels, engineering units, sampling rate, etc.). The filename appears on the first line of the header. A descriptive title can be placed on the first and second line starting at column 17. Header information is placed in blocks that start with a label that is surrounded by angle brackets: <TEST>, <SAMPLING>, and <CHANNELS>. Blank lines in the header section are ignored.

The data section begins with the label <DATA>, followed by one line, that is ignored, followed by the numeric data, organized in columns, with each column representing one channel of data. The data may be delimited by commas, tabs, or spaces, with one row representing one time sample of all signals.

The program requires the acceleration data be in the units of meters per second, squared (m/s^2). For convenience of the user, and for those files in units other than m/s^2, the user may specify a conversion factor and have the program convert the data to m/s^2.

IMPORTANT NOTES:

• THE KEYWORDS MUST BE INCLUDED AS THEY ARE SHOWN BELOW IN RED (words left of the colons), INCLUDING COLONS.

• In version 4.x and earlier, RIDEPAD DATA MUST BE TRIAXIAL AND GIVEN IN X, Y, Z ORDER.

• In version 5.0, RIDEPAD DATA CAN BE IN ANY ORDER, BUT THE DATA MAY ONLY SPAN 512 CHARACTERS ACROSS.

The following is an example illustrating the BCR file data structure.

```
A_Sample.BCR     THIS IS A SAMPLE TITLE
                 Human response to shock and vibration

<TEST>
Description:          Phase 2 - Vehicle Data
Test Location:        outside track
Vehicle Type:         SUV
Seat Position:        Driver
Test Terrain:         gravel
Vehicle Speed:        15 mph

<SAMPLING>
Number of Channels:   4
Samples per channel: 25298
Sampling rate (Hz):   416.667
Signal duration (s): 60.7

<CHANNELS> -------------------------123456--12345678
01   seat x acceleration              m/s^2    XAC seat
02   seat y acceleration              m/s^2    YAC seat
03   seat z acceleration              m/s^2    ZAC seat
04   seat z acc driver                m/s^2    ZAC seat

<DATA> ***************************************************
[One line after <DATA> is required but is ignored]
   0.05     0.21     0.14     0.22
   0.05     0.19     0.15     0.12
   0.05     0.22     0.15     0.10
   0.05     0.18     0.16     0.11

 ----- etc...
```

APPENDIX O: MUSCULOSKELETAL TRAUMA (SEGMENTAL VIBRATION) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Provide data regarding the materiel type, manufacturer, acceleration (m/s^2), frequency (Hz) and use scenarios for each piece of equipment.

(2) Do not exceed the daily recommended Threshold Limit Value (TLV) listed below. Place an advisory to this effect in the equipment user manuals.

(3) Ensure workers exposed to continuous hand-arm vibration (HAV) take a 10-minute break each hour. Place an advisory to this effect in the equipment user manuals.

(4) Ensure an advisory is placed in the equipment user manuals to issue Soldiers anti-vibration gloves meeting American National Standards Institute (ANSI) S3.40 2002 specifications.

(5) Place an advisory in equipment user manuals for workers to keep hands warm and dry while using vibration power tools.

Health effects. Hand-arm vibration is associated with such illnesses as carpal tunnel syndrome, Reynaud's phenomenon and Hand-arm Vibration Syndrome (HAVS). The HAV is usually transmitted through equipment that a worker uses. Exposure to HAV over many years may cause decreased hand muscle strength, and may cause numbness or cold sensitivity. Several factors increase the risk of injury: vibration frequency, vibration magnitude (acceleration), exposure time, temperature and tool design.

Medical criteria. The American Conference of Government Industrial Hygienists (ACGIH) provides TLVs for the control of hand-arm vibrations. Although adherence to the TLVs alone does not guarantee the control of HAVS, they provide a nationally recognized standard to base comparisons of exposure data.

ACGIH TLVs for Hand Arm Vibration

Total Daily Exposure Duration	Value of the dominant, frequency-weighted, root-mean-square, component acceleration which shall not be exceeded In meters per second squared (m/s^2)
4 hours and less than 8	4
2 hours and less than 4	6
1 hour and less than 2	8
Less than 1 hour	12

References.

(1) 2010 TLVs and BEIs, Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, American Conference of Government Industrial Hygienists, Cincinnati, OH, 2010.

APPENDIX P: MUSCULOSKELETAL TRAUMA (HEAD SUPPORTED MASS) IHHAR ELEMENT

Data requirements and initial recommendations.

(1) Provide the weight of the head supported mass (HSM), a measure of load asymmetry imposed by the HSM along the x and z axes, and any acceleration/deceleration forces associated with the activities where the materiel will be used.

(2) Disperse the weight of so load is distributed more evenly over the head and its gravitational axis.

(3) No additional devices should be attached to the helmet during parachute operations.

(4) If materiel is used when sitting, ensure chairs are equipped with posterior head/neck support that can be adjusted so that wearers can achieve proper head-on-neck alignment.

(5) Enforce administrative controls that provide users with periodic rest periods. During this rest period, the materiel should be removed. Provide users with instructions on postural alignment and exercises that may provide temporal relief from biomechanical stress.

Health effects. Devices that increase the weight supported by the Soldier's head and neck will possibly shift the center of head-supported mass off the centerline, placing the user at risk of acute and chronic neck injury and degraded performance.

Medical criteria. Currently approved damage risk criterion are not available for health hazards associated with head-supported devices. Medical and safety personnel, specifically the U.S. Army Aeromedical Research Laboratory (USAARL), are currently working to develop damage risk criteria for head-supported devices. If discomfort develops in vibration environments when the material is attached and deployed, Soldiers should be advised to either stow or remove the item from the helmet unless operational conditions dictate otherwise. Unless operational conditions dictate otherwise, Soldiers riding on military vehicles should be advised to remove helmet-mounted devices to reduce the risk of acute neck injury if the vehicle is involved in an accident. Soldiers should continue to wear the basic helmet for its blunt and ballistic impact protection.

APPENDIX Q: COMPARISON MATRIX ACOUSTIC ENERGY (STEADY-STATE NOISE)

	CRITERIA							
REPORT TITLE	**1**	**2**	**3**	**4**	**5**	DATE		
69-MP-0AFY-09	X	X	X	X	O	JAN 09	**1**	MIL-STD-1474 Requirement 1
69-MP-08VH-09	X	X	X	X	X	FEB 09		
69-MP-0BA4-09	X	X	X	X	O	MAY 09	**2**	Measure all personnel positions
69-MP-0B8F-09	X	X	X	X	O	MAY 09		
69-MP-09YY-08	X	O	O	O	O	JUN 08	**3**	Measure in and around
EXACT	X						**4**	85dBA contour measured
MISSING	O							
							5	Measure each use scenario

N = 25
K = 18

APPENDIX R: COMPARISON MATRIX ACOUSTIC ENERGY (IMPULSE NOISE)

	CRITERIA					
REPORT TITLE	**1**	**2**	**3**	DATE		
69-MP-2438-08	X	X	X	APR 08	**1**	collect impulse noise data IAW MILSTD 1474D Req 4
69-MP-09YY-08	X	O	O	JUN 08		
69-MP-0BDY-09	X	X	X	MAY 09	**2**	all crew/passenger and user positions, source if unmanned
69-MP-0B8F-09	X	X	X	MAY 09		
69-MP-0AFY-09	X	X	X	JAN 09	**3**	collect appropriate data for 140dB contour
EXACT	X					
MISSING	O					

N = 15
K = 13

APPENDIX S: COMPARISON MATRIX ACOUSTIC ENERGY (BLAST OVERPRESSURE)

	CRITERIA				
REPORT TITLE	**1**	**2**	DATE		
69-MP-0BDY-09	X	X	MAY 09	**1**	conduct testing IAW BOP Program Guidance
69-MP-09YY-09	X	O	JUN 08		
				2	submit info contained in BOP information form
EXACT	X				
MISSING	O				

N = 4
K = 3

APPENDIX T: COMPARISON MATRIX BIOLOGICAL SUBSTANCES - PATHOGENIC ORGANISMS (BLOODBORNE)

	CRITERIA						
REPORT TITLE	**1**	**2**	**3**	**4**	DATE		
69-MP-MRAP-07	X	X	X	X	AUG 07	**1**	Reference 29CFR Part 1910.1030 lists 7 key aspects
69-MP-06EQ-07	X	X	X	X	FEB 07		1. scope
							2. exposure control plans
							3. methods of compliance
							4. post-exposure evaluation and follow-up
							5. hazard communication
							6. information & training
							7. record keeping
						2	user develops SOPs and includes them in TMs
						3	design for decontamination
						4	storage of RMW
EXACT	X						
MISSING	O						

N = 8
K = 8

APPENDIX U: COMPARISON MATRIX BIOLOGICAL SUBSTANCES - PATHOGENIC ORGANISMS (WATERBORNE)

	CRITERIA							
REPORT TITLE	**1**	**2**	**3**	**4**	**5**	DATE		
69-MP-02L8-04	O	X		O	O	SEP 04	**1**	water txt, storage, handling info (designs, specs, materials, chemicals, process)
69-MP-4845-04	X	O	X	X	X	AUG 04		
69-MP-02SY-04	X	O	X	X	X	OCT 04	**2**	provide admin, design, engineering controls
							3	water generation systems capable of good quality for mission duration
EXACT	X							
MISSING	O						**4**	assess materiel during extreme conditions (temp, shock, vibration, dust)
N/A								
							5	provide use, test results, water analysis of pathogens, disinfectant residual, NBC

N = 14
K = 9

APPENDIX V: COMPARISON MATRIX BIOLOGICAL SUBSTANCES (PATHOGENTIC ORGANISMS)

	CRITERIA																
REPORT TITLE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	DATE
69-MP-2199-04	X	X	O														MAY 04
69-MP-09YY-08	O	X	O	X	X	X	X	X	X	O	O	X	X	X	X		JUN 08
69-MP-2438-08	O	O	X	X	X	X	X	X	X	X	X	X	X	X	X		MAY 08
69-MP-02ZW-04							X	X	X	X	X	O	O	X	X		AUG 04
69-MP-02L5-04														X			JUN 04
69-MP-01KG-04	X	X	X	X	X	O						O	O	X	X	X	DEC 04
EXACT	X																
MISSING	O																
N/A																	

1	POT H2O - plumbing approved by NSF/UPC for potable water
2	POT H2O - storage approved by NSF/UPC for potable water
3	POT H2O - designed for easy cleaning, draining, service, maintenance, sanitization
4	WASTE - total crew
5	WASTE - mission duration
6	WASTE - designed for easy cleaning, draining, service, maintenance and sanitization
7	TOILET - total crew
8	TOILET - mission duration
9	TOILET - refer to Title 29 CFR
10	TOILET - handwash facilities
11	TOILET - sanitize body contact surfaces
12	FOOD - total crew
13	FOOD - mission duration
14	FOOD - meet NSF/UL or other lab consensus
15	FOOD - designed for easy draining, cleaning, service, maintenance and sanitization
16	POT H2O - mission duration for total crew on board

N = 55
K = 40

APPENDIX W: COMPARISON MATRIX CHEMICAL SUBSTANCES

	CRITERIA							
REPORT TITLE	**1**	**2**	**3**	**4**	**5**	DATE		
69-MP-0BDV-09	X	X	X	X		JAN 09	**1**	MISC – MSDS available, include specific use, handling, storage, disposal in TM
69-MP-0BC8-09	X	X	X	X		FEB 09		
69-MP-08VH-09			X	X		FEB 09	**2**	MISC - eliminate/reduce # of toxic/haz chemicals by design or substitute
69-MP-0A2T-09	X	X				MAR 09		
69-MP-0BA4-09	X	X				MAY 09	**3**	ENGINE - design so exhaust & other chems don't enter breathing zone
69-MP-0BDY-09					X	MAY 09		
69-MP-0B8F-09	X	X	X	X		MAY 09	**4**	ENGINE - provide detailed design info, eng. exh. product data IAW TOP 2-2-614
69-MP-0AFY-09	X	X	X	X		JAN 09		
							5	WEAPON - provide test results of combustion hazards IAW TOP 2-2-614
EXACT	X							
MISSING	O							
N/A								

N = 23
K = 23

APPENDIX X: COMPARISON MATRIX OXYGEN DEFICIENCY

	CRITERIA								
REPORT TITLE	**1**	**2**	**3**	**4**	**5**	**6**	DATE		
69-MP-06EQ-07	X	X	X	X	X	O	FEB 07	**1**	Ensure system provides required rate of fresh/recirc air IAW MILSTD1472F
69-MP-0BA4-09	O		O	O	O	X	MAY 09		
69-MP-09YY-08	X		X	X	X	X	JUN 08	**2**	Provides general ventilation and LEV to capture airborne hazards
69-MP-0AFS-09	X	O	O	O	O	O	DEC 08		
69-MP-MRAP-07	X	X	X	X	X	O	AUG 07	**3**	Provide design info
								4	Provide max # personnel
EXACT	X							**5**	cab/shelter volume
MISSING	O								
N/A								**6**	conduct test data IAW TOP 1-2-610

N = 28
K = 17

APPENDIX Y: COMPARISON MATRIX RADIATION ENERGY - OPTICAL RADIATION

	CRITERIA												
REPORT TITLE	1	2	3	4	5	6	7	8	9	10	11	12	DATE
69-MP-09YY-08	X	X	X	X	X	X	X	X	X	X	X	X	JUN 08
69-MP-2438-08	X	X	X	O	X	X	X	X	X	X	X	X	MAY 08
69-MP-MRAP-07	X	X	O	O	X	X	X	X	X	X	X	X	AUG 07
69-MP-06EQ-07	X	X	O	O	X	X	X	X	X	X	X	X	FEB 07
69-MP-048P-06	X	X	O	O	X	X	X	X	X	X	X	O	MAY 06
EXACT	X												
MISSING	O												

1	technical POC
2	list of sources
3	name/nomenclature/use
4	Location
5	transmitter wavelength
6	pulse width
7	pulse repetition rate
8	beam divergence
9	exit beam diameter
10	laser medium
11	day-view optics
12	safety features

N = 60
K = 52

APPENDIX Z: COMPARISON MATRIX RADIATION ENERGY - RADIOFREQUENCY RADIATION

	CRITERIA											
REPORT TITLE	1	2	3	4	5	6	7	8	9	10	11	DATE
69-MP-MRAP-07	X	X	X	X	X	X	X	X	X	X	X	AUG 07
69-MP-06EQ-07	X	X	X	X	X	X	X	X	X	X	X	FEB 07
69-MP-04C2-06	O	O	O	O	O	O	X	X	O	O	O	DEC 06
69-MP-066P-07	X	X	X	X	X	X	X	X	X	X	X	OCT 05
69-MP-09YY-08	X	X	X	X	X	X	X	X	X	X	X	JUN 08
EXACT	X											
MISSING	O											

1	technical POC
2	Frequency
3	Peak
4	average power output
5	pulse repetition frequency
6	pulse width
7	duty cycle
8	antenna type
9	Size
10	Gain
11	Location

N = 55
K = 46

OMITTING REPORT 69-MP-04C2-60
N = 44
K = 44

APPENDIX AA: COMPARISON MATRIX RADIATION ENERGY - IONIZING RADIATION

	CRITERIA										
REPORT TITLE	1	2	3	4	5	6	7	8	9	10	DATE
69-MP-2438-08	X	X	X	■	X	X	■	X	X	X	APR 08
69-MP-02ZW-04	X	X	X	■	X	X	■	X	X	X	AUG 04
EXACT	X										
MISSING	O										
N/A	■										

1	Isotope
2	chemical or physical form
3	amount of activity
4	condition *new criteria
5	operating parameters (x-ray device)
6	radiation output
7	system certification * new criteria
8	operating parameters (neutron source)
9	neutron emission rate
10	average energy output

N = 16
K = 16

APPENDIX BB: COMPARISON MATRIX TEMPERATURE EXTREMES

	CRITERIA						
REPORT TITLE	**1**	**2**	**3**	**4**	DATE		
69-MP-0BA4-09	X	X	X	X	MAY 09	**1**	provide test data on H/C systems based on MILSTD1472F
69-MP-0AFS-09	X	X	X	X	DEC 08		
69-MP-09YY-08	X	O	O	X	JUN 08	**2**	provide WBGT at occupant head, chest, foot
69-MP-09CW-08	X	O	O	O	JUN 08		
69-MP-08VH-09	X	X	X	X	FEB 09	**3**	simulate all heat gains
						4	provide test data on systems based on TOP 2-2-816/610
EXACT	X						
MISSING	O						

N = 20
K = 15

APPENDIX CC: COMPARISON MATRIX MUSCULOSKELETAL TRAUMA (LIFT AND CARRY)

	CRITERIA						
REPORT TITLE	**1**	**2**	**3**	**4**	DATE		
MP-69-0BDY-09	X	O	O	O	MAY 09	**1**	collect information on HHA Lift Analysis Worksheet
69-MP-0BDV-09	O	X	X	X	JAN 09		
69-MP-0BC8-09	O	X	X	X	FEB 09	**2**	apply design guidance in MIL-STD-1472F para 5.9.11
69-MP-0B31-09	O	X	X	O	FEB 09		
69-MP-0AFY-09	O	X	X	X	JAN 09	**3**	determine weight/lift requirements, include warning labels
69-MP-0AFS-09	O	X	X	O	DEC 08		
						4	provide info on lift requirements, labels, TM guidance
EXACT	X						
MISSING	O						

N = 20
K = 12

APPENDIX DD: COMPARISON MATRIX MUSCULOSKELETAL TRAUMA (WHOLE BODY VIBRATION)

	CRITERIA				
REPORT TITLE	**1**	**2**	DATE		
69-MP-SATS-07	X	X	JUL 07	**1**	Test data collected IAW ISO 2631-1, 2631-5
69-MP-06EQ-07	X	X	FEB 07		
69-MP-0BDV-09	X	X	JAN 09	**2**	Report in BC Research Format
69-MP-0BC8-09	X	X	FEB 09		
69-MP-MRAP-07	X	X	AUG 07		
EXACT	X				
MISSING	O				

N = 10
K = 10

APPENDIX EE: COMPARISON MATRIX MUSCULOSKELETAL TRAUMA (SEGMENTAL VIBRATION)

	CRITERIA							
REPORT TITLE	**1**	**2**	**3**	**4**	**5**	DATE		
69-MP-03PR-05	X	X	X	X	X	APR 05	**1**	ACGIH TLVs included
69-MP-7300-07	X	X	X	X	X	FEB 07		
							2	do not exceed TLVs
EXACT	X						**3**	10 minute break each hour
MISSING	O							
							4	anti-vibration gloves ANSI S3.40
							5	warm & dry hands

N = 10
K = 10

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Table 8
Phi (ϕ) Coefficient for Hazard Categories (All Report Types)

	HAZARD																
HAZARD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	*	-0.18	-0.13	+0.09	+0.11	+0.27	**+0.47**	-0.03	+0.24	+0.14	**+0.46**	**+0.38**	+0.13	+0.25	+0.05	-0.08	+0.06
2		*	+0.28	-0.01	-0.05	+0.02	-0.05	+0.03	-0.02	-0.01	-0.08	-0.02	-0.17	-0.01	+0.04	-0.05	+0.08
3			*	+0.01	-0.03	-0.01	-0.05	+0.01	-0.06	+0.01	-0.08	-0.04	-0.06	-0.01	+0.05	-0.03	-0.01
4				*	**+0.31**	+0.08	+0.15	0	+0.02	0	+0.11	+0.11	+0.06	+0.01	-0.01	-0.02	-0.01
5					*	+0.11	+0.12	-0.04	+0.04	0	+0.01	+0.06	+0.04	+0.02	-0.01	-0.02	-0.01
6						*	+0.28	-0.04	+0.10	+0.07	+0.26	+0.26	+0.03	+0.08	0	-0.02	+0.04
7							*	+0.01	+0.21	+0.16	**+0.63**	**+0.54**	+0.07	+0.22	+0.04	-0.03	+0.07
8								*	+0.05	+0.1	0	0	-0.02	-0.08	-0.03	-0.04	+0.03
9									*	+0.06	+0.23	+0.21	+0.23	+0.11	+0.04	-0.05	+0.07
10										*	+0.15	+0.1	+0.05	+0.03	-0.03	-0.01	+0.04
11											*	**+0.66**	+0.05	+0.23	+0.02	-0.04	+0.01
12												*	-0.03	+0.26	+0.05	-0.02	-0.02
13													*	-0.03	+0.07	-0.03	-0.03
14														*	+0.07	-0.04	-0.02
15															*	-0.01	0

16																*	-0.01
17																	*

Table 11
Hazard Frequency by Severity, Probability, and RAC (HHA)

	HAZARD SEVERITY, PROBABILITY AND RAC																					
HAZARD #	1					2			3					4			5					
	1,A	1,B	1,C	2,A	2,B	1,D	2,C	3,A	1,E	2,D	3,B	3,C	4,A	2,E	3,D	4,E	3,D	3,E	4,B	4,C	4,D	4,E
1				6	3		224			87	1	20		2	11			1			2	14
2	1	2		48	16		189			10		1		1	4						2	7
3				1	4		7		1	5		1	4		1			1				1
4				2	2	1	11			9	1	9			5						1	1
5				1	3		10			7	4	12			7							
6	1	6	9		20	34	77		4	145	14	143		3	121	1	1	2	2	7	15	53
7		1	5		3	10	10	2	1	19	3	8	1		12						2	16
8			1		6	1	22	1	1	17	7	13			26			1	1	15	6	3
9							3	1		5		20		1	25				2	65	17	20
10				1	1		3			1	1	13		3	23			1	5	20	16	5
11		1	5		4	7	42	1		24	5	15		1	4							12
12						1	14	1		16	4	9		1	1			1				16
13					4		16	3		24	23	46		2	29			2		3	4	
14			2	1	1		3	3		3	11	9	5		9			1	5	4	3	2
15												1									2	
16							2							1	1			1	1			
17										2												

Table 12
Hazard Frequency by Severity, Probability, and RAC (Initial)

	HAZARD SEVERITY, PROBABILITY AND RAC																					
HAZARD #	1					2			3					4			5					
	1,A	1,B	1,C	2,A	2,B	1,D	2,C	3,A	1,E	2,D	3,B	3,C	4,A	2,E	3,D	4,E	3,D	3,E	4,B	4,C	4,D	4,E
1					1		18			12		2			1							1
2				1	1		14															
3										2												
4							1					1										
5				1	3		5				1	6						1				
6			6			4	7		1	22	8	26			21				3	1	1	3
7			1			3	1			1	1				1							
8							4			3		1			4					2	1	1
9												4			1			1	1	9	2	1
10										1				1			3			1		
11			1		1		3			5		4			1				1			2
12										1		3										2
13							3	1		4	1	5			5							
14											1										2	1
15																						
16					1																	
17																						